

NGM.COM JUNE 2011

NATIONAL GEOGRAPHIC

The **BIRTH** *of* **Religion**

The World's First Temple

Africa's Super Park 60

The Secret World of Child Brides 78

Crazy Creatures in Tide Pools 100

Can China Go Green? 116

Why Rare Earths Are in Almost Everything 136

Göbekli Tepe, Turkey
circa 9600 B.C.



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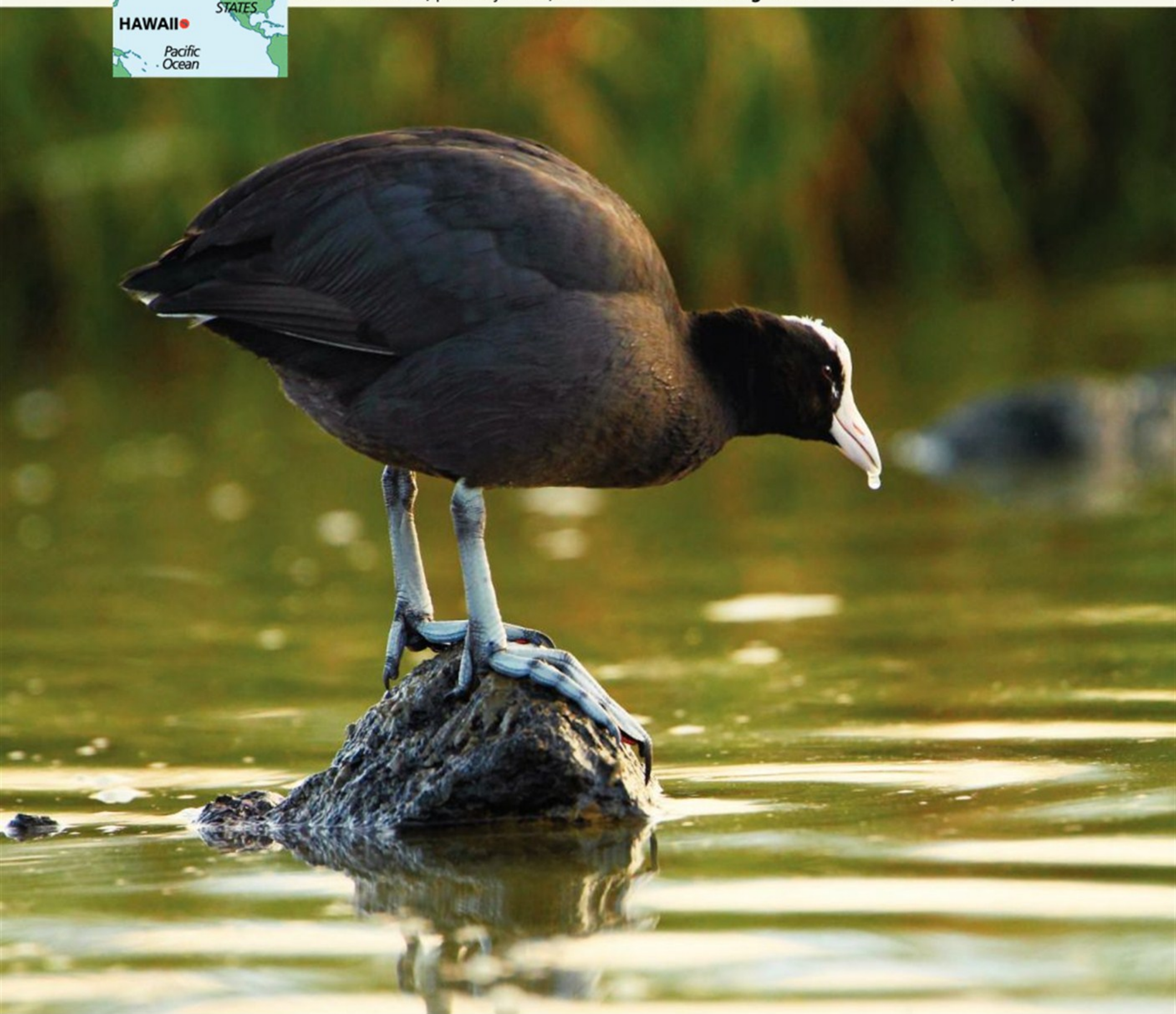
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Hawaiian Coot (*Fulica alai*)

Size: Head and body length, 38 - 39 cm (15 - 15.4 inches); wingspan, approx. 65 cm (25.6 inches)

Weight: Approx. 500 g (17.6 oz) **Habitat:** Streams, marshes, ponds and other bodies of water on the Hawaiian Islands, primarily Kauai, Oahu and Maui **Surviving number:** Estimated at 2,000 - 4,000



Photographed by Kurt W. Baumgartner

WILDLIFE AS CANON SEES IT

Why settle for waterfront? The Hawaiian coot goes one step further, building nests directly on the water. These floating masses of vegetation are large—about 24 inches in diameter—and provide access to a menu of aquatic plants, tadpoles and small fish. Females lay four to ten eggs, which both parents incubate. They defend their nest vigorously, but if predators do destroy the nest or take their eggs the pair may simply re-nest. The coot needs to be persistent and

adaptable to survive, given that so much of its habitat has been drained or otherwise altered. But facing a host of introduced predators as well as habitat loss, its home on the water is under siege.

As we see it, we can help make the world a better place. Raising awareness of endangered species is just one of the ways we at Canon are taking action—for the good of the planet we call home. Visit canon.com/environment to learn more.

Canon



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STEPHANIE SINCLAIR

At age ten, Nujood Ali of Yemen took a taxi to a courthouse, fleeing her abusive husband. Today she is divorced and back in school.

June 2011

34 Birth of Religion

Turkey's 11,600-year-old pillars reflect a surprising new theory about the origins of worship.

By Charles C. Mann Photographs by Vincent J. Musi

60 Africa's Super Park

Cheetahs and elephants are lucky to live in the eco-minded nation of Namibia.

By Alexandra Fuller Photographs by Frans Lanting

78 Too Young to Wed

The bride may be 14, 10, 5. The practice of child marriage is illegal—yet still thrives.

By Cynthia Gorney Photographs by Stephanie Sinclair

100 Brimming Pools

Rich and risky, tide pools host sea stars, anemones, harpooning worms.

By Mel White Photographs by David Liittschwager

116 Can China Go Green?

No other country is investing so heavily in clean energy. But no other country burns as much coal.

By Bill McKibben Photographs by Greg Girard

136 Rare Earths

They're the secret (Chinese) ingredients of (almost) everything high-tech.

By Tim Folger

WILD *Times*



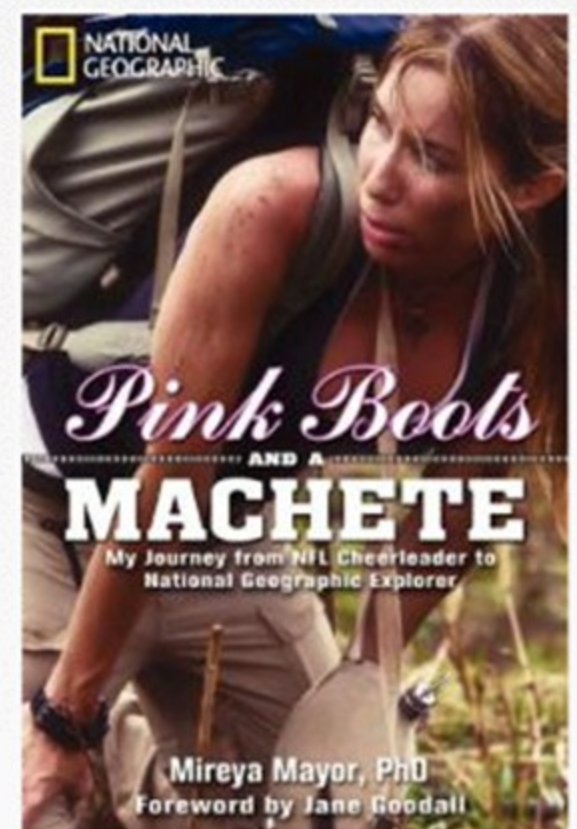
Mayor is a former NFL cheerleader, a Fulbright scholar, a National Science Foundation Fellow, and two-time Emmy Award-nominated television correspondent. She appears as a host on the Nat Geo WILD television network, is a former field correspondent for the *National Geographic Ultimate Explorer* television series, and starred in the 2009 History Channel series, *Expedition Africa: Stanley and Livingstone*.



A first look at Mireya Mayor's new book, *Pink Boots and a Machete: My Journey from NFL Cheerleader to National Geographic Explorer*.

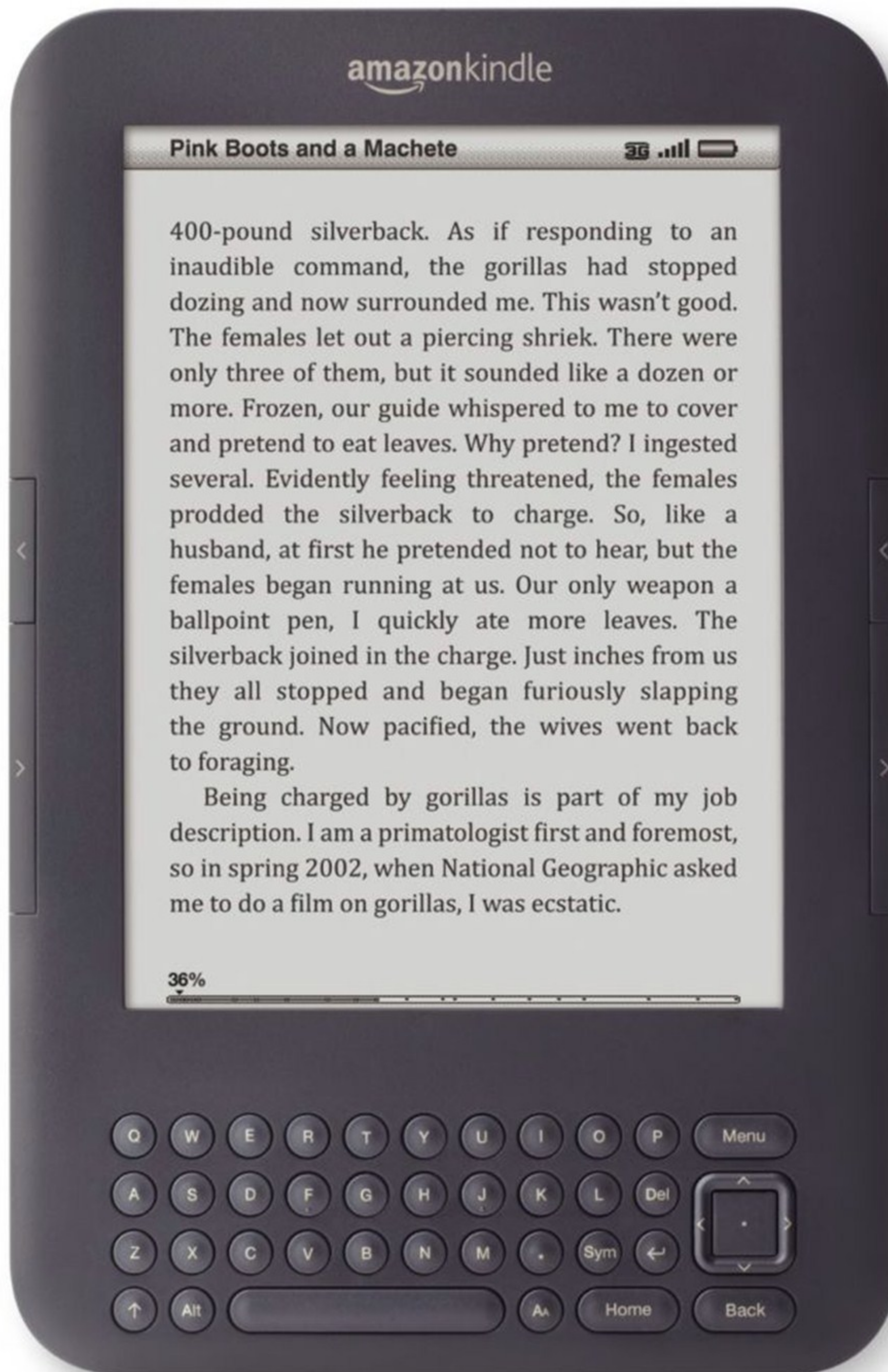
Excerpted from Chapter Seven:
Gorilla Warfare

Deep in the heart of darkness in the lush rain forest of the Congo, the gorillas were dozing under the rays of morning sun that pierced the dense vegetation, exuding their infectious, albeit misleading, aura of calm. I, on the other hand, was swatting at sweat bees trying to make their way into my ears and up my nose. These bees are attracted to salt in human sweat, and although their sting is almost painless, their constant presence is a total pain in the butt. Especially when one is trying to observe gorillas and share in their Zen-like state. Ironically, the more I waved my hands to get rid of the annoying creatures, the more I sweated and added to my appeal. By the dozens, they clustered on my arms and legs and dive-bombed into my eyes. What satisfaction it gave me to crush them.



While digging a bee out of my eye, I heard a noise behind me. Like most primates, gorillas are usually heard before they are seen. Not having a mirror, I was using the lens of my camera to pick sweat bees out of my pupils. Suddenly, reflected behind me was a gorgeous,

Continued on Kindle



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Red Alert ▶

The dye derived from tiny insects may soon be listed on product labels.

The King's Head

A skull once sold at auction has been identified as Henry IV's.

Too Many Plant Labels

Nearly 500,000 names are redundant.

Polar, Meet Grizzly ▶

The two species, which diverged 200,000 years ago, are mating.

A New Job for Aging Ants

When their jaw blades grow dull, leafcutter ants switch careers.



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Harness the Sea

Scientists are tapping wave energy.

Sunlight in the Dark

In rural Africa micro-solar systems are a safe sub for kerosene lamps.

Swayed by Speech

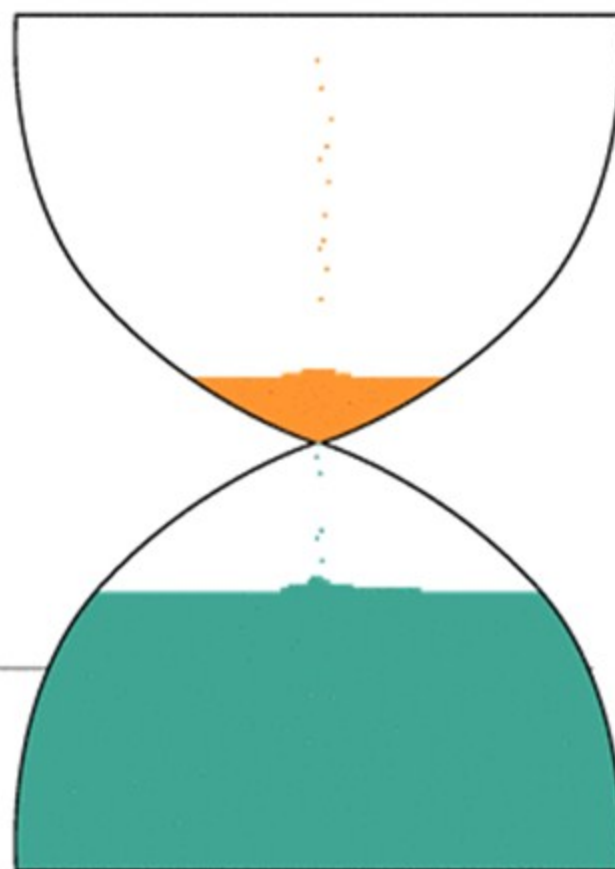
Whom do you like and trust? The answer may lie in a person's accent.

How Many Have Lived? ▶

A demographer calculates Earth's human population for all time.

Insecure Passwords

"1234" is a bad idea. So is "dragon."



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E-GEOGRAPHIC

On ngm.com

Your Shot: Namibia Dunes

Skeletal trees plus orange dunes equal a photo op. To see readers' versions of our picture on pages 60-1, or to send in your own, visit ngm.com/namibia-park.

On the iPad

Envisioning Göbekli Tepe

The drawing of the ancient temple on pages 44-5 began as a clay model, which was flown to Europe for expert vetting and then digitized.

Tap Into Tide Pools

A touch of the screen will pump up the tiny creatures on pages 102-3.



On the Cover

An angry beast eyes a boar on a pillar at Turkey's Göbekli Tepe, the oldest known temple.

Photo by Vincent J. Musi

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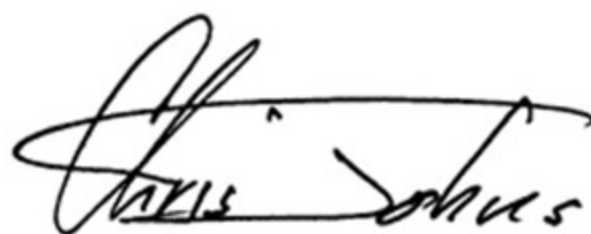
charles **SCHWAB**

New Beginnings

Sometime around 1439, a German craftsman from the city of Mainz swiped an inked roller over a frame filled with metal type, made words on paper, and created the world of print publishing. More than 500 years after Johannes Gutenberg, we have electronic fonts and pixelated pages, but words, whether printed on paper or glowing on a computer screen, continue to inspire, excite, and teach.

Those of us who have watched electronic publishing evolve are excited by the portability of tablets such as the iPad and the value they add to the magazine experience. In publishing our electronic version of *National Geographic* and special apps like *50 Greatest Photographs* (right), we do what we've always done: tell and show stories, but in a richer way. You can play video and audio, interact with graphics, and jump to the Web. Imagine standing in the middle of an image of Stonehenge in the English countryside and spinning it around, seeing it in three dimensions instead of two, or watching a time-lapse photo sequence of a ship being sunk to form an artificial reef in the Atlantic Ocean.

We are always working to make this magazine better. Electronic publishing is only part of that effort. This month we debut an expansion of our Departments sections—new offerings in both the front and back of the magazine—we hope you will enjoy. What's not new is this: We still value presenting the world in all its complexity to our readers, and getting it right. Says David Griffin, who helped spearhead our venture into e-publishing, "The killer app is information."



"The killer
app is
information."



The iPad makes *National Geographic* photos seem to burst from the screen.



FIND THE APPS

The *National Geographic* magazine and *50 Greatest Photographs* iPad applications can be downloaded from the App Store.

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Opium Wars

I read your report on the ongoing struggle to eradicate poppy growing in Afghanistan with great interest but also with sadness. This campaign is funded by the Western allies but seems largely unsuccessful and brutal. Rather than using force against the growers, who are mostly poor farmers,

- why don't we buy the crops ourselves and turn it not into heroin but into medical morphine, for which there is great demand? That way we remove the crops and the farmers from the clutches of the drug lords, while at the same time giving the farmers a legitimate source of income.

MIKE DAVIS
Cheltenham, England

I advise the current Afghanistan government not to refer to the federal strategy against opium as a war. Instead, it's like fighting cancer: prevention coupled with treatment, accompanied by research.

EVAN DALE SANTOS
Adelanto, California

The only way to stop people from growing opium is to enhance their standard of living—not support them with more money when they promise

not to plant it. They must realize that opium can't make them rich, even if it makes them more money than other crops.

ERIC MEI
Suchow, China

"Opium Wars" presents the growers, users, U.S. military, Afghan police and politicians all working at cross-purposes as the bewildered U.S. taxpayer looks on. The author tells of progress in police stations built and highways paved at great

cost—but the images of Afghans watching their crops being destroyed tell the true story. If they pick up arms to defend themselves and feed their children, who can blame them?

DONALD LYON
Brownsville, Oregon

Relics to Reefs

I enjoyed reading about the ships. I served aboard the U.S.S. *Muliphen* (AKA-61), eventually sunk off Port St. Lucie, Florida, in 1989. At one of our ship's reunions, one of my buddies brought a film he had obtained of our ship after a few years underwater. During its showing, one of us mournfully said, "Look at our poor home with the fish swimming in and out of her." Another crew member piped up, "Better her without us than with us."

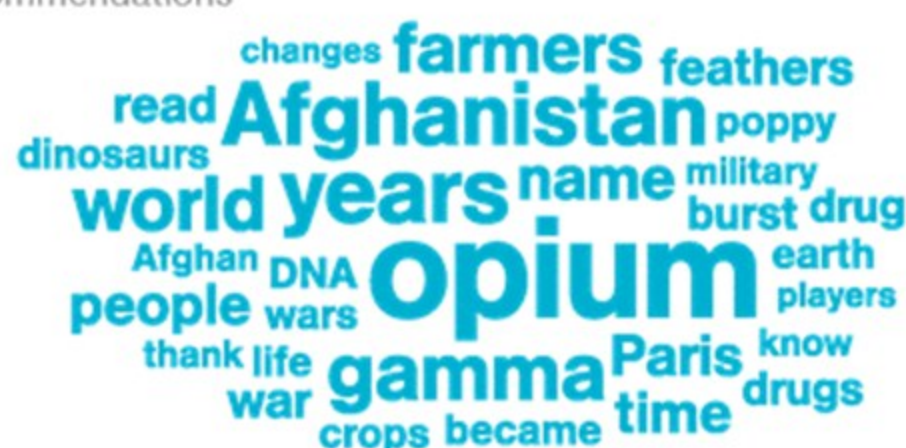
FREDERICK M. RODRIGUEZ
Western Springs, Illinois

Corrections

DECEMBER 2010, WILD: FLOWER BEDS In the short article about bees that build nests out of flower petals, the bee shown was incorrectly identified as a female.

FEEDBACK These graphics reflect the most common words found in your letters about our February issue.

Commendations



Criticisms



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#19

The Happy Pup

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Shark Men

Sundays, 10 p.m. ET

Captain Brett McBride and his co-captain Jody Whitworth continue their quest for knowledge of the elusive great white shark. Find out how they and their expert team are faring in *Shark Men*, now in its second season. This time they'll catch, tag, and release even more of the mighty sea creatures—all in the name of science. Get on board Sundays at 10 p.m. on the National Geographic Channel.

Expert anglers McBride (top, at left) and Whitworth (at right) examine a shark aboard their ship.



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Mission Programs



Founded in 1888, the National Geographic Society has supported more than 9,000 explorations and research projects, adding to our knowledge of earth, sea, and sky.

MISSION *To develop new lifesaving drugs from venom.*

Snake Secrets Finding deadly snakes is seldom easy, but sea kraits are an exception. As they rose from the waves in Fiji, I grabbed four in rapid succession. Luckily, they rarely bite. Holding one by the head, I drew blood from its heart. Then I set it free. The DNA in its cells contains raw information about toxins in the venom. These are among nature's best killing molecules, the focus of my research at the University of Chicago.

I've been fascinated by snakes ever since I raised puff adders in my room as a teenager in Budapest. Since then, as a herpetologist, pilot, scuba diver, and wildlife photographer, I've traveled to 134 countries to study all kinds of venomous snakes. My team unlocked

the mystery of why cobras are not killed by their own venom. Our research may lead to new, lifesaving drugs to treat autoimmune diseases like diabetes and multiple sclerosis.

Scientists have studied fewer than a thousand animal toxins, from which a dozen or so medications are derived. But some 20 million more exist. I aim to collect samples of as many as I can. This presents challenges: I've crossed paths with pirates, rebels, and forest elephants; survived six venomous snake bites; and been sprayed in the face by a spitting cobra. Because I have allergies to both venom and antivenom, I've learned to be more careful. Explorers have to know the limits. Then we can push those limits further. —Zoltan Takacs



When handling venomous snakes like these sea kraits, Takacs wears two thick gloves on each hand to avoid bites.

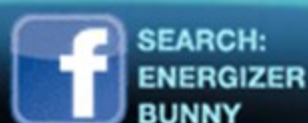


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VISIONS




Ireland

Frolicking on glacial ice on a summer's day? Part illusion, thanks to Edgar Müller's perspective painting "The Crevasse." Created over five days on a pier's pavement in Dún Laoghaire, the faux precipice covers more than 2,000 square feet.

PHOTO: EDGAR MÜLLER



A detailed close-up photograph of a viperfish's head and jaw. The fish's skin is dark and textured, with several small, glowing bioluminescent spots visible. The jaw is open, revealing a row of sharp, pointed teeth. The background is dark and out of focus, with some faint light sources visible.

Atlantic Ocean

Fearsome predator of the deep, a viperfish displays its meal-clinching assets: bioluminescent spots thought to lure prey in dark waters and a set of ferocious fangs. The teeth are strictly for seizing, as food is swallowed whole.

PHOTO: SOLVIN ZANKL
NPL/MINDEN PICTURES





England

The shell of Brighton's West Pier emerges in snowy outline during a night exposure lit by promenade lamps onshore. A bustling site for entertainment in the 1920s, it fell into neglect before a 2003 fire left only bare bones.

PHOTO: TOBY SMITH,
REPORTAGE BY GETTY IMAGES



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Visit nationalgeographic.com/emerging to see and hear the Emerging Explorers.

Cultural Educator Aziz Abu Sarah

forges cross-cultural understanding amid the Israeli-Palestinian conflict, using education, media outreach, and tourism to bridge political and religious divides.



Photo: Christiane Marie Abu Sarah



Photo: Conrad Anker

Environmental Scientist Jennifer Burney

tackles the interwoven problems of world hunger and climate change through innovative technologies that improve the way food is produced, distributed, and cooked.



Photo: Zacharie SEROTAMOU B



Photo: Cheryl Zook/NGS

Entomologist Dino Martins

highlights the crucial role insects play in pollinating crops and educates African farmers in how to protect insects and ecosystems essential to food supplies and family survival.

Planetary Scientist and Astrobiologist Kevin Hand

explores our planet's most extreme environments to help plan a NASA mission to Jupiter's moon Europa, extending the search for life beyond Earth.



Photo courtesy of Kevin Hand



Photo: Matthew Muspratt

Wastewater Engineer Ashley Murray

creates waste-based businesses whose profits improve sanitation and health in developing countries, proving waste has economic value as a re-usable resource.

Paleontologist Jørn Hurum

unearths groundbreaking fossil finds on a remote Arctic island, revealing an entire marine ecosystem with never-before-seen species that connect new evolutionary dots.



Photo: Hans Arne Nakrem



Photo: Erik Forsyth/Rockjumper Birding Tours

Ornithologist and Conservation Ecologist Çagan Hakki Şekercioğlu

studies the causes and consequences of worldwide bird extinctions, applying his research to grassroots, community-based conservation efforts in the developing world.

Wildlife Conservationist Paula Kahumbu

connects frontline conservationists with people who want to help, using the power of the Internet to raise awareness and donations for projects saving wildlife and wild places worldwide.



Photo: Cheryl Zook/NGS



Photo: Georgie Hollidge

Wildlife Ecologist and Filmmaker Adrian Seymour

promotes conservation through scientific research and documentary filmmaking, exposing pressures that put both wildlife and local communities at risk.

Bioengineer Kakani Katija

dives into revolutionary research on how the movements of even tiny ocean animals can make a major impact on global weather patterns and the overall health of our seas.



Photo: Heather Hoxsey



Photo courtesy of Hayat Sindi

Science Entrepreneur Hayat Sindi

makes life-saving tests accessible to remote, impoverished communities through innovative devices that can monitor health under extreme conditions.

Ecologist Sasha Kramer

brings low-cost public sanitation to Haiti's most marginalized people, transforming human waste into fertilizer to boost agriculture, curb disease, reduce environmental degradation, and rebuild dignity.



Photo: Hadas



Photo: Sebastien Viaud

Conservationist Tuy Sereivathana

develops dramatically successful solutions to save Cambodia's endangered elephants, while rebuilding agriculture, education, and community life in a nation emerging from decades of violence.



Rindra Ramasomanana Antananarivo, Madagascar

As the sun rises in Bekily, Madagascar, mango-eating children cast long shadows on the dry ground. Ramasomanana, a 27-year-old freelance photographer, took this shot from a bridge. He was documenting the island nation's parched southern region.



Steven Nestor
Dublin, Ireland

At Ireland's War Memorial Gardens, Nestor, 38, a photo technician at Griffith College Dublin, captured his son cycling through a drained pond strewn with petals. The site honors Irish soldiers—like Nestor's grandfather—who fought in World War I.

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Defy Pain, Defy Aging, Defy Fatigue

This is my story

I used to be more active. I used to run, play basketball, tennis, football... I was more than a weekend warrior. I woke up every day filled with life! But now, in my late 30's, I spend most of my day in the office or sacked out in front of the TV. I rarely get to the gym – not that I don't like working out, it's the nagging pain in my knees and

Customer Satisfaction Speaks for Itself!

4 out of 5 customers purchase a 2nd pair within 3 months.

ankles. Low energy and laziness has got me down. My energy has fizzled and I'm embarrassed to admit that I've grown a spare tire (I'm sure it's hurting my love life). Nowadays I rarely walk. For some reason it's just harder now. Gravity has done a job on me.



Wear them and you'll know

That's what my doctor recommended. He said, "Gravity Defyer shoes are pain-relieving shoes." He promised they would change my life—like they were a fountain of youth. "They ease the force of gravity, relieving stress on your heels, ankles, knees and back. They

boost your energy by propelling you forward." The longer he talked,

the more sense it made. He was even wearing a pair himself!

Excitement swept through my body like a drug

I received my package from GravityDefyer.com and rushed to tear it open like a kid at Christmas. Inside I found the most amazing shoes I had ever seen – different than most running shoes. Sturdy construction. Cool colors. Nice lines... I was holding a miracle of technology. This was the real thing.

GDefy Benefits

- Relieve pain
- Ease joint & spinal pressure
- Reduce fatigue & tiredness
- Be more active
- Have more energy
- Appear taller
- Jump higher, walk and run faster
- Have instant comfort
- Cool your feet & reduce foot odor
- Elevate your performance

I put them on and all I could say was, "WOW!" In minutes I was out the door. I was invincible; tireless in my new Gravity Defyer shoes. It was as if my legs had been

replaced with super-powered bionics.

What the doctor promised was all correct. No more knee pain. I started to lose weight. At last, I was pain free and filled with energy! I was back in the game. Gravity had no power over me!



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Nothing to lose: 30 Day Free Trial*

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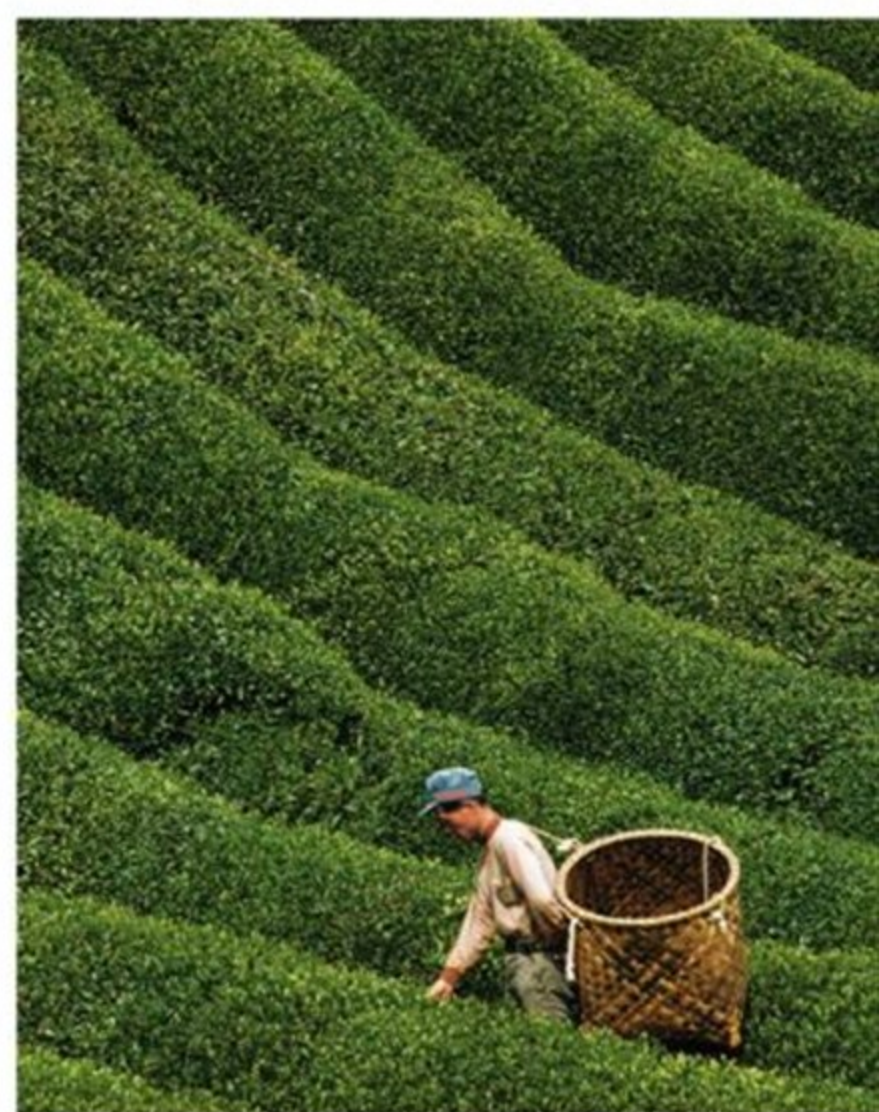
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**DAVID DE
ROTHSCHILD**
Founder
Adventure Ecology

Red Alert

A brilliant red dye derived from tiny insects once treasured by the Spanish conquistadores gives some modern foods and cosmetics an alluring blush. In a small number of people, though, it can cause swelling, rashes, or respiratory problems. The U.S. has now mandated that the coloring be identified as “cochineal extract” or “carmine” on product labels. Previously, vague phrases such as “color added” were acceptable.

Native to the New World, cactus-eating cochineal bugs are dried and crushed to produce a powdered dye. Beginning in the 16th century, Europeans of wealth and status wore clothing reddened with rare cochineal. The deep, durable color was even used to produce the British Army’s famous red coats for more than 200 years. Cochineal harvesting declined after the invention of cheap synthetic dyes in the 1800s, but it has rebounded—mostly in Peru and the Canary Islands—with the dye’s use as a natural alternative to artificial colorings. —A. R. Williams

Red dye made from cochineal insects (one enlarged above) colors a range of products.



Food and Drink

Candies, cookies, yogurts, gelatins, and juices may contain cochineal, but enhanced reds in the U.S. usually come from artificial red No. 40.



Textiles

Embroidery thread, fabric for art, and couture gowns are still hand-colored with cochineal. Industrial dyers tend to use cheaper synthetics.



Cosmetics

Anything red, pink, or brown in the makeup aisle—lipstick, blush, mascara, eyeliner, eye shadow, nail polish—may contain cochineal.

NOW



Return of the King

How heavy is the head that wore the crown? About five pounds. It also bears distinctive knife cuts, a pierced ear, and a lesion near the nose. Those forensic clues, along with preserved tissues and organs, helped a multidisciplinary team confirm that an embalmed skull (right) belonged to Henry IV, the beloved French king who was assassinated in 1610.

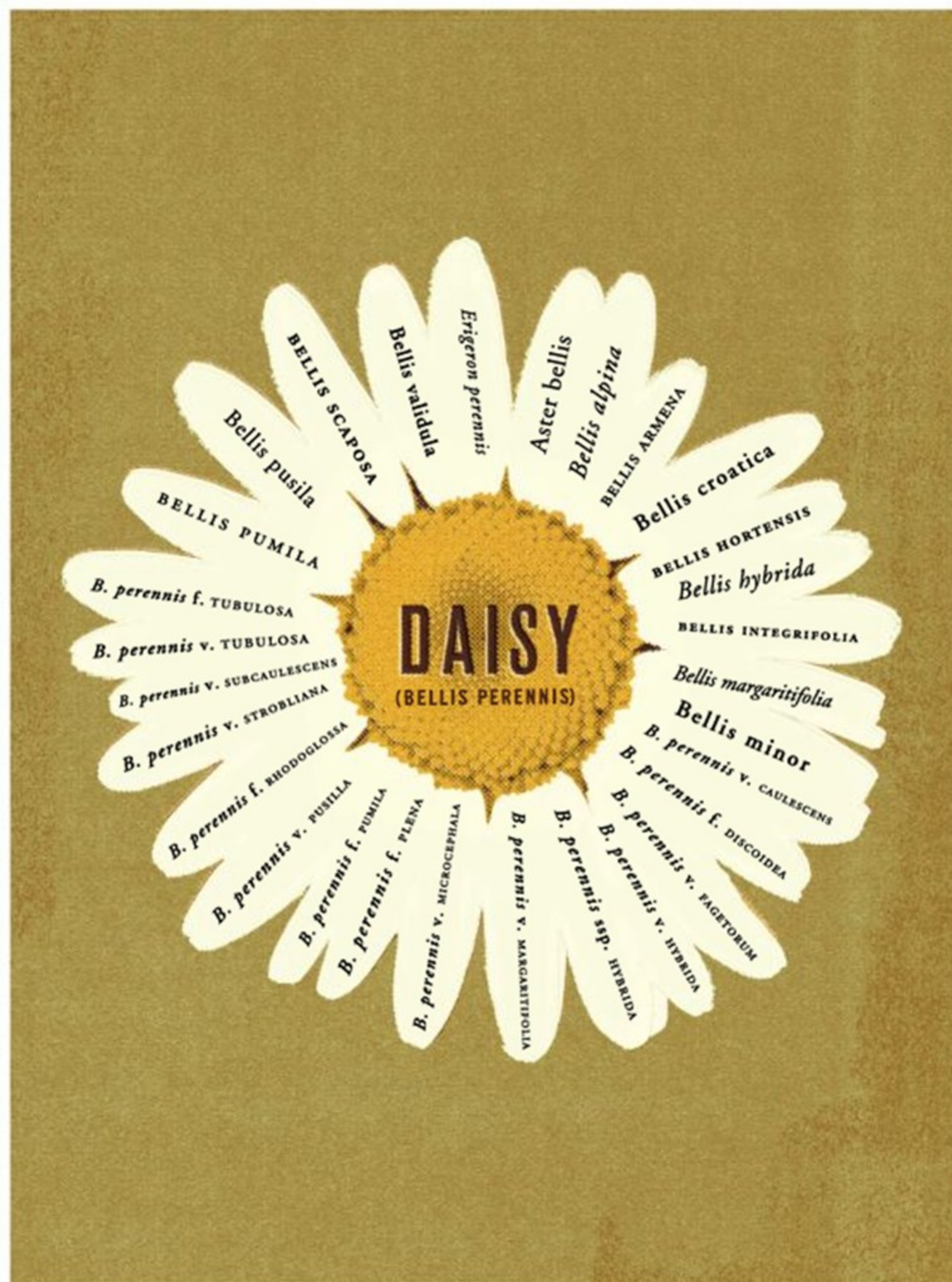
After the ruler's remains were desecrated during the French Revolution, his head vanished for more than a hundred years. A pate said to be Henry's was sold at a Paris auction in the early 20th century, then moved quietly among private collections. From 1955 until last year it was in a tax collector's attic.

Now, after nine months of scientific and historical scrutiny, it's in the hands of a royal descendant. With its reinterment at the Basilica of St.-Denis near Paris, this weary head may finally be able to rest in peace. —Jeremy Berlin



The head of France's King Henry IV lies with a Legion of Honor medal that bears his portrait.





29 Names, Same Plant

In 1753 Swedish naturalist Carl Linnaeus published *Species Plantarum*, a book describing some 6,000 plant species that became the foundation of modern plant nomenclature. The list of names has since ballooned to 1.05 million, but of those, only around 300,000 are now confirmed to be unique species. Nearly half a million others, it turns out, are redundant.

The scientific moniker for English oak has 314 synonyms, the common daisy (above) 29, and the giant sequoia 18. Those are just a few identified so far in the Plant List, a working database created in 2010 by the Missouri Botanical Garden and London’s Kew Gardens after years of vetting. “It’s like people. We have different eye colors, shapes, and sizes, but we’re all people,” says botanist Bob Magill. “There’s huge variation within a species.” —Luna Shyr

Hybrid Bears on the Move

In the past five years two odd-looking bears, with white fur and brown patches, have been killed by hunters in the Canadian Arctic. DNA tests confirmed it: Polar and grizzly bears, after starting to diverge 200,000 years ago, are interbreeding in the wild. Climate change seems to be driving their reunion. But to what end?

Evolutionary biologist Brendan Kelly says that as natural barriers like sea ice vanish, 22 Arctic species are at risk of rapid hybridization. That could be bad news for polar bears, which rely on specialized adaptations to survive. Kelly says if “pizzlies” in the wild lack some of those vital Arctic traits—as zoo-born hybrids* (below) seem to—interbreeding could further imperil an already threatened species.

—Jeremy Berlin

*A MIX OF POLAR AND BROWN BEARS, OF WHICH GRIZZLIES ARE A SUBSPECIES





"After reviewing the assembly and precision of the Minuit movement, I'm most impressed."

—George Thomas
Noted Watch Historian

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This timepiece is a night owl. It ignores curfew and stays up much later than it should. This watch never goes to bed early because it knows that life gets infinitely more interesting after dark. It knows that magical things happen between dusk and dawn. And just like you, the *Stauer Minuit Timepiece* doesn't want to miss a moment.

Inspired by the mystery of late nights, the *Minuit* is an exceptional Swiss-made timepiece in a category all its own. Even more impressive than its distinctive design is the price. Call today and you can own the stunning *Swiss-Made Minuit* for only \$199.

What happened when the sun went down. I was wide awake when I dreamed up the design for Stauer *Minuit*. It was the middle of the night at the top of the world. My wife and I were celebrating in a hotel in the Swiss Alps overlooking Lake Lugano. The world was asleep and the stars seemed low enough to touch. I'll never forget the view that night, an endless blue heaven speckled with stars. You don't get to see that kind of sky in the big city. We stayed up to watch the sun rise through the mountains. Right away I missed the night.

The Stauer Minuit is simple, yet striking. It took the designers in Switzerland months to get the look of this timepiece just right. If your favorite color is blue, here's your chance to see it in a whole new way. Inside, the *Minuit* is driven by a precision Swiss quartz movement and crafted in Switzerland, home to the world's noblest watchmaking traditions.

In honor of that perfect Alpine sky, we added a touch of sparkle to the shimmering, metallic blue face with a trio of Austrian crystal rounds at the twelve, three and nine o'clock positions. Golden Roman numerals pop against the rich black of the outer dial and an easy-to-read date window sits at the six. The *Minuit* secures with a genuine black leather strap and gold-fused buckle.

Your Satisfaction is 100% Guaranteed. Try the Stauer *Minuit Swiss-Made Timepiece* for 30 days. We're confident that it will captivate you, but if for any reason it doesn't, send the watch back within 30 days for a prompt and courteous refund. I guess the Swiss have a way with heavenly blue and Stauer has a way of keeping prices down to Earth. Thank your lucky stars.

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- Genuine black leather strap - Fits a 6 3/4"-8 1/2" wrist


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A Second Career As the foragers of their colony's caste system (right), media leafcutter ants start out with mandibles as sharp as surgical scalpels. But over the course of their lives, the repetitive slicing of leaves into small disks dulls their V-shaped blades. Rather than retire, the ants shift their role to just carrying sheared-off vegetation to the nest, where food production begins.

Observing Panama's *Atta cephalotes*, University of Oregon's Robert Schofield and his team found that ants with dulled blades used about twice as much energy and time to carve a leaf as their still sharp colleagues, triggering the job switch. "It's an advantage of social living that we're familiar with," says Schofield. "Humans who can no longer do certain tasks can still make worthwhile contributions to society." —Erin Friar McDermott

Rank and File

Majors *Clear trails and defend colony*

Medias *Cut out and transport pieces of leaves*

Minors *Chew leaf bits into a pulpy mass*

Minims *Cultivate food and nurse the young*

ET CETERA

Ten elements in the **PERIODIC TABLE**, including carbon, nitrogen, and oxygen, are getting revised atomic weights. • A study finds that several **CORAL SPECIES** around Japan have shifted north some 700 miles, possibly due to warmer oceans. • **KOREACERATOPS**: the name given to a dinosaur, based on a rare fossil find on the Korean Peninsula. • California's **COASTAL FOG** occurs some 33 percent less frequently than in the early 20th century, say University of California, Berkeley scientists.

For arthritis patients, it's simple physics:

A body in motion...tends to stay in motion.



Celebrex can help relieve arthritis pain... so you can keep moving.

It's simple physics — a body in motion tends to stay in motion. Staying active can actually relieve arthritis symptoms. But if you have arthritis, staying active can be difficult.

That's why you should talk with your doctor about treatment options, like prescription Celebrex.

- Just one 200mg Celebrex a day can provide 24-hour relief for many with arthritis pain and inflammation.* Relief that can help your body stay in motion.
- In clinical studies with osteoarthritis patients, Celebrex is proven to improve pain, stiffness and daily physical function.
- Celebrex is not a narcotic.

When it comes to relieving arthritis pain, you and your doctor need to balance the benefits with the risks — and find the right treatment for you.

So ask your doctor about Celebrex. It could be an important step towards keeping *your* body in motion.

Visit celebrex.com

or call 1-888-CELEBREX for more information.

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit fda.gov/medwatch or call 1-800-FDA-1088.

*Individual results may vary.

Important Safety Information:

Like all prescription NSAIDs, CELEBREX may increase the chance of heart attack or stroke that can lead to death. This chance increases if you have heart disease or risk factors for it, such as high blood pressure or when NSAIDs are taken for long periods.

CELEBREX should not be used right before or after certain heart surgeries.

Serious skin reactions, or stomach and intestine problems such as bleeding and ulcers, can occur without warning and may cause death. Patients taking aspirin and the elderly are at increased risk for stomach bleeding and ulcers.

Tell your doctor if you have: a history of ulcers or bleeding in the stomach or intestines; high blood pressure or heart failure; or kidney or liver problems.

CELEBREX should not be taken in late pregnancy.

Do not take CELEBREX if you've had an asthma attack, hives, or other allergic reactions to aspirin, any other NSAID medicine or certain drugs called sulfonamides.

Life threatening allergic reactions can occur with CELEBREX. Get help right away if you've had swelling of the face or throat or trouble breathing.

Prescription CELEBREX should be used exactly as prescribed at the lowest dose possible and for the shortest time needed.

See the Medication Guide on the next page for important information about Celebrex and other prescription NSAIDs.



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CELEBREX
(CELECOXIB CAPSULES) 100 mg
200 mg

For a body in motion™

Medication Guide
for Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)
(See the end of this Medication Guide for a list of prescription NSAID medicines.)

What is the most important information I should know about medicines called Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)?

NSAID medicines may increase the chance of a heart attack or stroke that can lead to death.

- This chance increases:
- with longer use of NSAID medicines
 - in people who have heart disease

NSAID medicines should never be used right before or after a heart surgery called a “coronary artery bypass graft (CABG).”

NSAID medicines can cause ulcers and bleeding in the stomach and intestines at any time during treatment. Ulcers and bleeding:

- can happen without warning symptoms
 - may cause death
- The chance of a person getting an ulcer or bleeding increases with:
- taking medicines called “corticosteroids” and “anticoagulants”
 - longer use
 - smoking
 - drinking alcohol
 - older age
 - having poor health

- NSAID medicines should only be used:
- exactly as prescribed
 - at the lowest dose possible for your treatment
 - for the shortest time needed

What are Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)?
NSAID medicines are used to treat pain and redness, swelling, and heat (inflammation) from medical conditions such as:

- different types of arthritis
- menstrual cramps and other types of short-term pain

Who should not take a Non-Steroidal Anti-Inflammatory Drug (NSAID)?
Do not take an NSAID medicine:

- if you had an asthma attack, hives, or other allergic reaction with aspirin or any other NSAID medicine
- for pain right before or after heart bypass surgery

- Tell your healthcare provider:
- about all of your medical conditions.
 - about all of the medicines you take. NSAIDs and some other medicines can interact with each other and cause serious side effects. **Keep a list of your medicines to show to your healthcare provider and pharmacist.**
 - if you are pregnant. **NSAID medicines should not be used by pregnant women late in their pregnancy.**
 - if you are breastfeeding. **Talk to your doctor.**

What are the possible side effects of Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)?

Serious side effects include: <ul style="list-style-type: none">• heart attack• stroke• high blood pressure• heart failure from body swelling (fluid retention)• kidney problems including kidney failure• bleeding and ulcers in the stomach and intestine• low red blood cells (anemia)• life-threatening skin reactions• life-threatening allergic reactions• liver problems including liver failure• asthma attacks in people who have asthma	Other side effects include: <ul style="list-style-type: none">• stomach pain• constipation• diarrhea• gas• heartburn• nausea• vomiting• dizziness
--	---

Get emergency help right away if you have any of the following symptoms:

- shortness of breath or trouble breathing
- chest pain
- weakness in one part or side of your body
- slurred speech
- swelling of the face or throat

Stop your NSAID medicine and call your healthcare provider right away if you have any of the following symptoms:

- nausea
- more tired or weaker than usual
- itching
- your skin or eyes look yellow
- stomach pain
- flu-like symptoms
- vomit blood
- there is blood in your bowel movement or it is black and sticky like tar
- skin rash or blisters with fever
- unusual weight gain
- swelling of the arms and legs, hands and feet

These are not all the side effects with NSAID medicines. Talk to your healthcare provider or pharmacist for more information about NSAID medicines.

Call your doctor for medical advice about side effects. You may report side effects to FDA at 1-800-FDA-1088.

Other information about Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)

- Aspirin is an NSAID medicine but it does not increase the chance of a heart attack. Aspirin can cause bleeding in the brain, stomach, and intestines. Aspirin can also cause ulcers in the stomach and intestines.
- Some of these NSAID medicines are sold in lower doses without a prescription (over-the-counter). Talk to your healthcare provider before using over-the-counter NSAIDs for more than 10 days.

NSAID medicines that need a prescription

Generic Name	Tradename
Celecoxib	Celebrex
Diclofenac	Cataflam, Voltaren, Arthrotec (combined with misoprostol)
Diflunisal	Dolobid
Etodolac	Lodine, Lodine XL
Fenoprofen	Nalfon, Nalfon 200
Flurbiprofen	Ansaid
Ibuprofen	Motrin, Tab-Profen, Vicoprofen* (combined with hydrocodone), Combunox (combined with oxycodone)
Indomethacin	Indocin, Indocin SR, Indo-Lemmon, Indomethagan
Ketoprofen	Oruvail
Ketorolac	Toradol
Mefenamic Acid	Ponstel
Meloxicam	Mobic
Nabumetone	Relafen
Naproxen	Naprosyn, Anaprox, Anaprox DS, EC-Naproxyn, Naprelan, Naprapac (copackaged with lansoprazole)
Oxaprozin	Daypro
Piroxicam	Feldene
Sulindac	Clinoril
Tolmetin	Tolectin, Tolectin DS, Tolectin 600

*Vicoprofen contains the same dose of ibuprofen as over-the-counter (OTC) NSAIDs, and is usually used for less than 10 days to treat pain. The OTC NSAID label warns that long term continuous use may increase the risk of heart attack or stroke.
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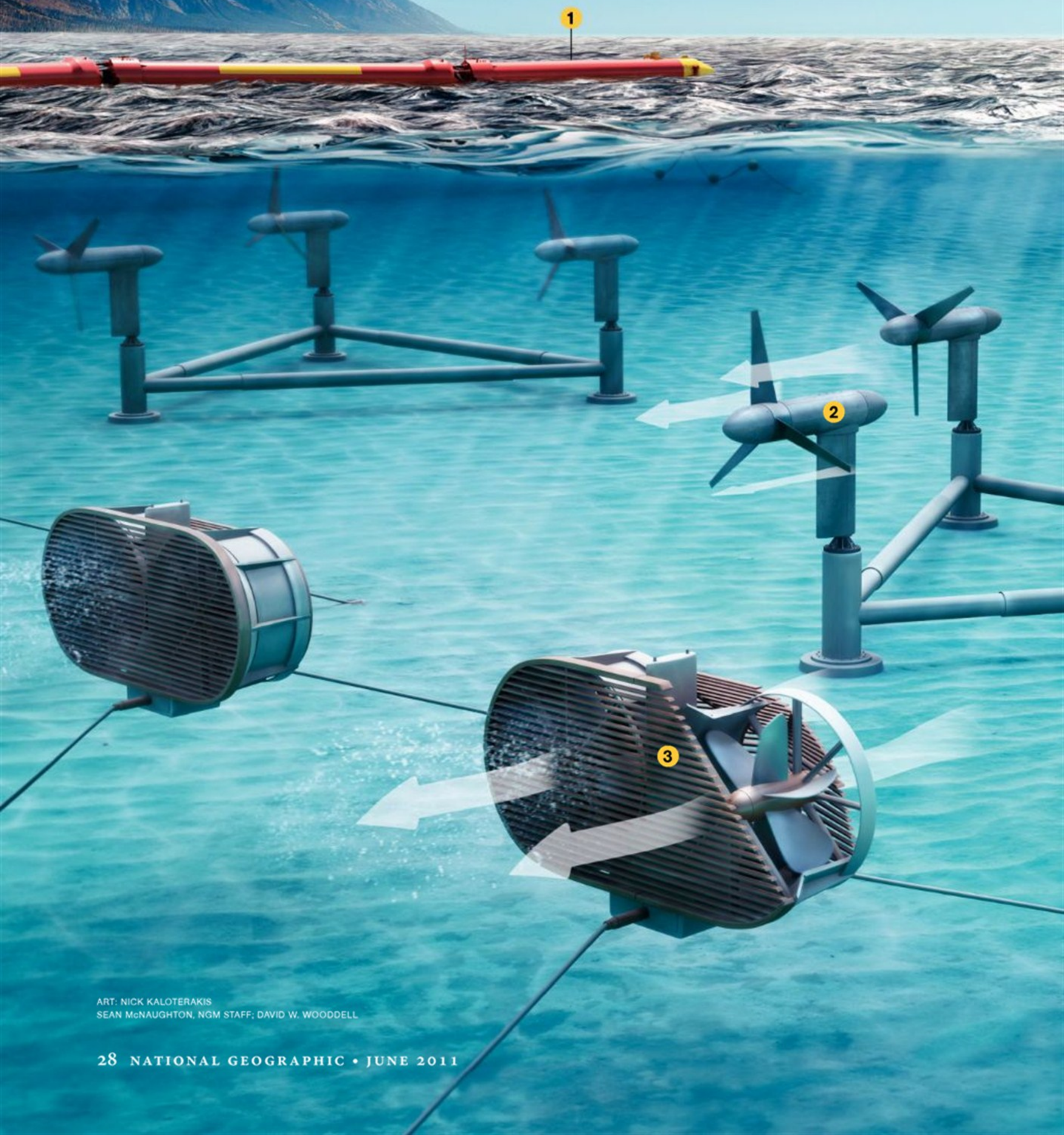
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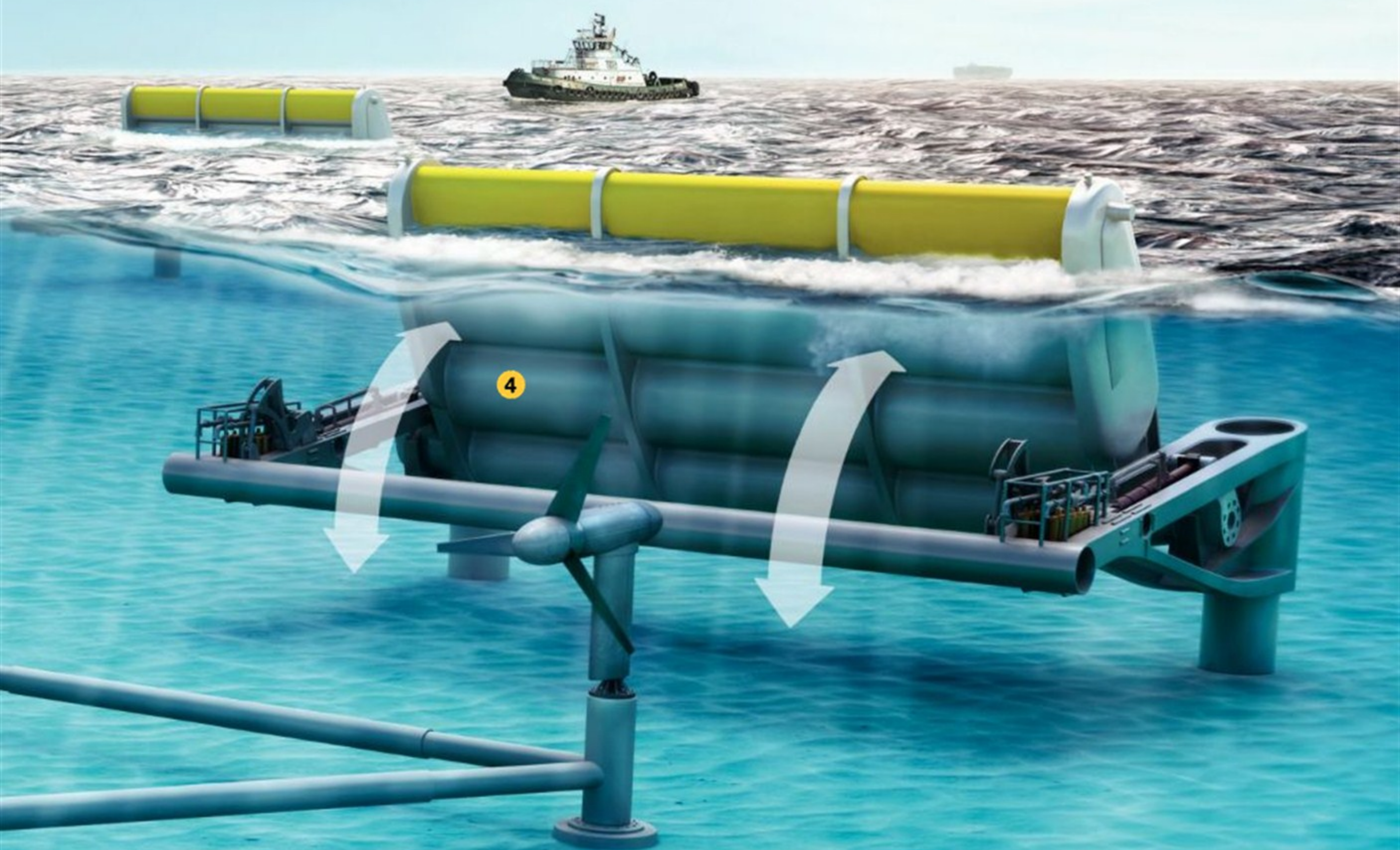
ART: NICK KALOTERAKIS
SEAN McNAUGHTON, NGM STAFF; DAVID W. WOODDELL

If you've ever been pummeled by a wave at the beach, you know that moving water packs a wallop. The Electric Power Research Institute estimates that wave and tidal energy could supply 7 percent of the electricity for the United States. In the United Kingdom, that contribution could be double.

Engineers are designing all sorts of devices to tap this clean, renewable energy—from “snakes” that jiggle over the water's surface to turbines that spin in a current. (Items illustrated here show

the diversity of wave power devices but wouldn't be implemented together.)

Since populations are often concentrated near coasts, energy from moving water can be produced close to where it's needed. And unlike wind energy, dependent on inconsistent gusts, this technology is as predictable as the tides. Technical and financial hurdles still exist, but projects are in the works for waters off Maine, New York, Oregon, Canada, and Scotland. Ocean power farms might be just over the horizon. —Juli Berwald



1

SEA SNAKES

Segments of the wave energy converter are the size of railroad cars, undulating on the surface to move internal hydraulic rams.

Developed by
Pelamis Wave Power

Length 600 feet

Weight 1,400 tons

2

FANS

Devices similar to wind turbines pivot with changes in tides.

Developed by
Verdant Power

Rotor diameter
16 to 33 feet

3

KITES

Arrays of small turbines moored by lines to seafloor or riverbed can generate power from relatively low flows.

Developed by
UEK Corporation

Diameter 8 feet

4

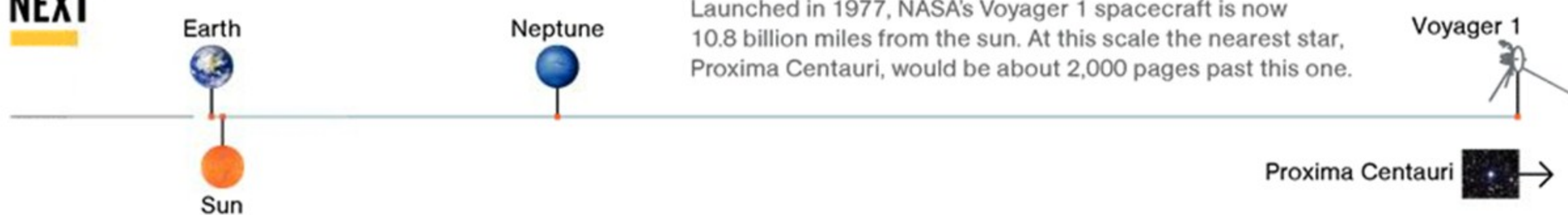
PADDLES

Hinged like an oyster's shell, buoyant flaps push water through a high-pressure pipeline to drive an onshore turbine.

Developed by
Aquamarine Power

Height 39 feet

NEXT

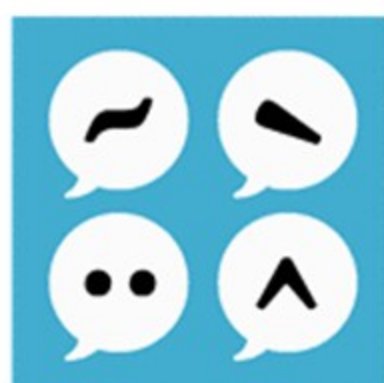


Sunlight in the Dark In rural East Africa, where nearly 90 percent of households are off the grid and large solar panels are costly, hazardous kerosene lamps are the norm. Enter portable micro-solar systems, which development groups are introducing for \$10 to \$25. These generate one or two watts—enough to power LED lights and recharge batteries—as well as income for local salespeople.

And micro-solar provides another kind of power. Dorica Magomba (above), a Maasai farmer in Tanzania's Iringa Region, uses it to scare hyenas away from livestock at night. "When you have light," says photographer Lynn Johnson, who met Magomba while working in the region, "you have courage." —Amanda Fiegl

Micro-solar Benefits

- 1 Cleaner and safer than kerosene lamps and disposable batteries
- 2 Cost recouped within five months; users avoid risk of rising fuel prices
- 3 Creates a new industry and extends work hours, boosting the local economy



ACCENTS AND PERCEPTION When it comes to the way we speak, accents reveal more than where we come from. Researchers at Germany's Friedrich Schiller University Jena found that speech trumps looks when people categorize someone based on those two traits alone. Accents may be key to social integration, as they can affect whether listeners perceive the speaker as being one of their own or part of a different group. Says Patricia Bestelmeyer, whose research at the University of Glasgow focuses on the brain's response to different accents: "They can influence how much you prefer or trust someone." —Luna Shyr



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A Helping Hand The surface of human skin is crowded with bacteria that would, if your immune system allowed it, cause serious infection. But researchers at the University of California, San Diego, have discovered that one bacterium in that mix, *Staphylococcus epidermidis* (a close cousin of methicillin-resistant *S. aureus*, or MRSA) may actually help fine-tune the immune system. To do its good work, *S. epidermidis* deploys a molecule that blocks aggressive inflammatory agents. If unchecked, those agents would ignite a rashy reaction around even a minor scrape. Good staph stays good only if locked outside by the skin's multiple defenses, though. Give that germ a way into a weakened body—like a ride on a surgical implant—and it can ignite a potentially fatal infection. —Vikki Valentine

Staphylococcus epidermidis is a common form of bacteria found on human skin. Invisible to the eye, bacteria are revealed when a handprint made in agar gel (above) is cultured in a laboratory.

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After 500 Years, Italy's Great Race Gets Its Trophy

Capture the romance of the Renaissance with the 30-carat Palio Ruby Necklace and get the 30-carat ruby bracelet... FREE!

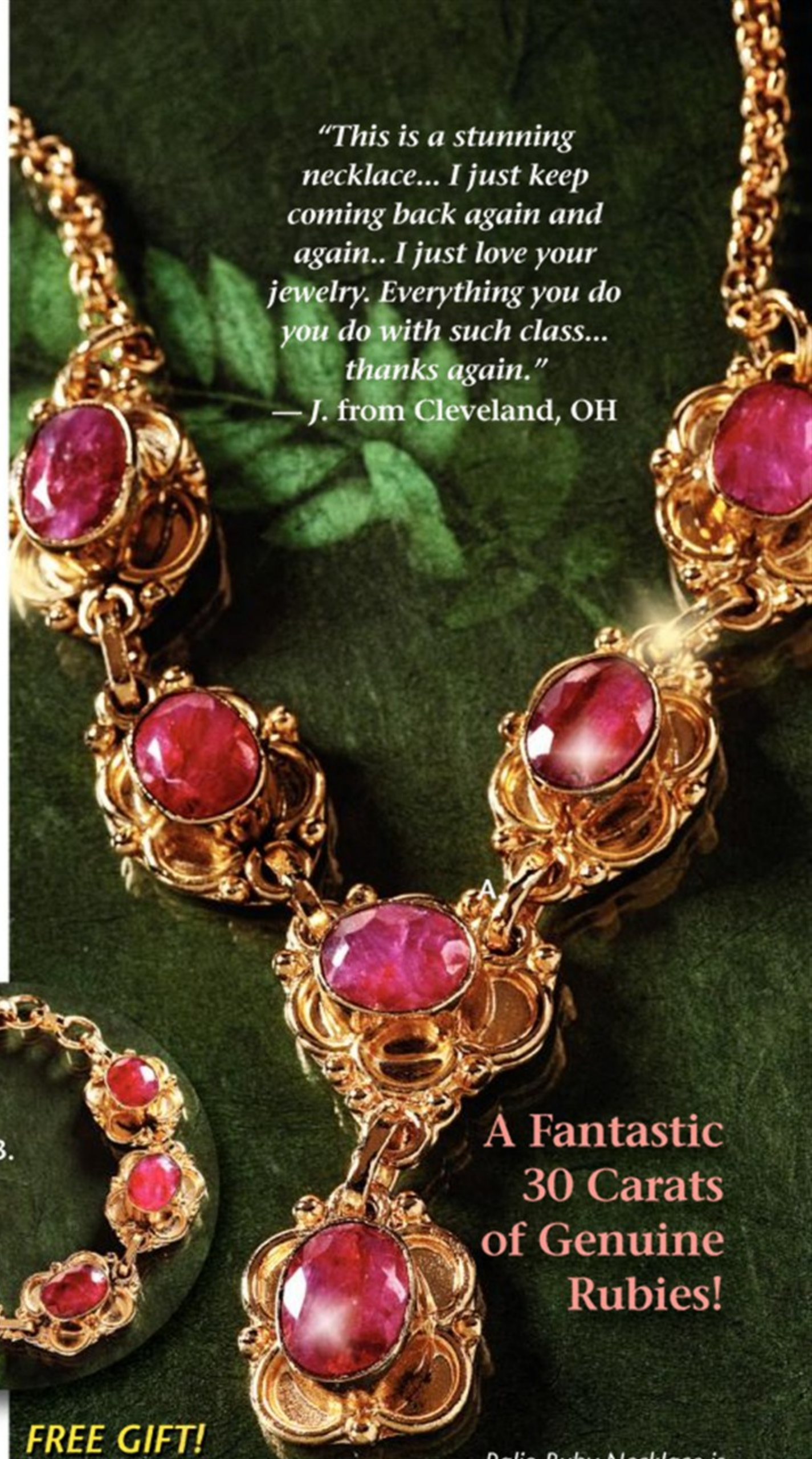
Trumpets blare and the Piazza del Campo explodes. You stand in a sea of thousands where nothing can be heard above the cheers. This is the start of the Palio di Siena, Italy's most historic horse race. Soon, ten bareback riders will risk their lives for 90 seconds of glory. But first comes a bishop's blessing followed by knights on horseback, clad in armor and followed by a regal procession of chariots, banners, and uniformed soldiers. This is the ritual and pageantry of the Italian Renaissance and you can't experience it anywhere else in the world. But finally, after five centuries, we've created a way for you to bring the spectacle home: the stunning **Palio 30-Carat Ruby Necklace**.

Genuine rubies capture the thrill of victory. The Siena tradition hasn't changed much since the Middle Ages. We wanted to create jewelry that would look and feel just as timeless. This is the same design you might see on a Renaissance beauty as she watched from luxury box seats. Back then, Italian royalty like the Borgias, Orsinis and Medicis were the only ones who could afford a 30-carat masterpiece of precious red rubies. Not any more.

A wedding of heritage and high fashion. Inside the floral-inspired, gold-fused metalwork, we've set six genuine ruby cabochons. These are the same stones coveted by European high-society for centuries and each of the six spectacular ovals (5 carats each) pops against the golden hue of the necklace. The 18" necklace finishes with a medium-weight, gold-fused cable chain that secures with a lobster clasp.

Buy 30 and get 30 FREE! While we're positive that you'll adore the necklace, such an extravagant event deserves more. You deserve more. That's why when you choose the **Palio Ruby Necklace**, we'll give you the **Palio Ruby Bracelet FREE!** That's right, in addition to the remarkable 30-carat necklace, you receive a bracelet loaded with another 30 gorgeous carats of genuine ruby... as our gift to you.

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"This is a stunning necklace... I just keep coming back again and again.. I just love your jewelry. Everything you do you do with such class... thanks again."

— J. from Cleveland, OH

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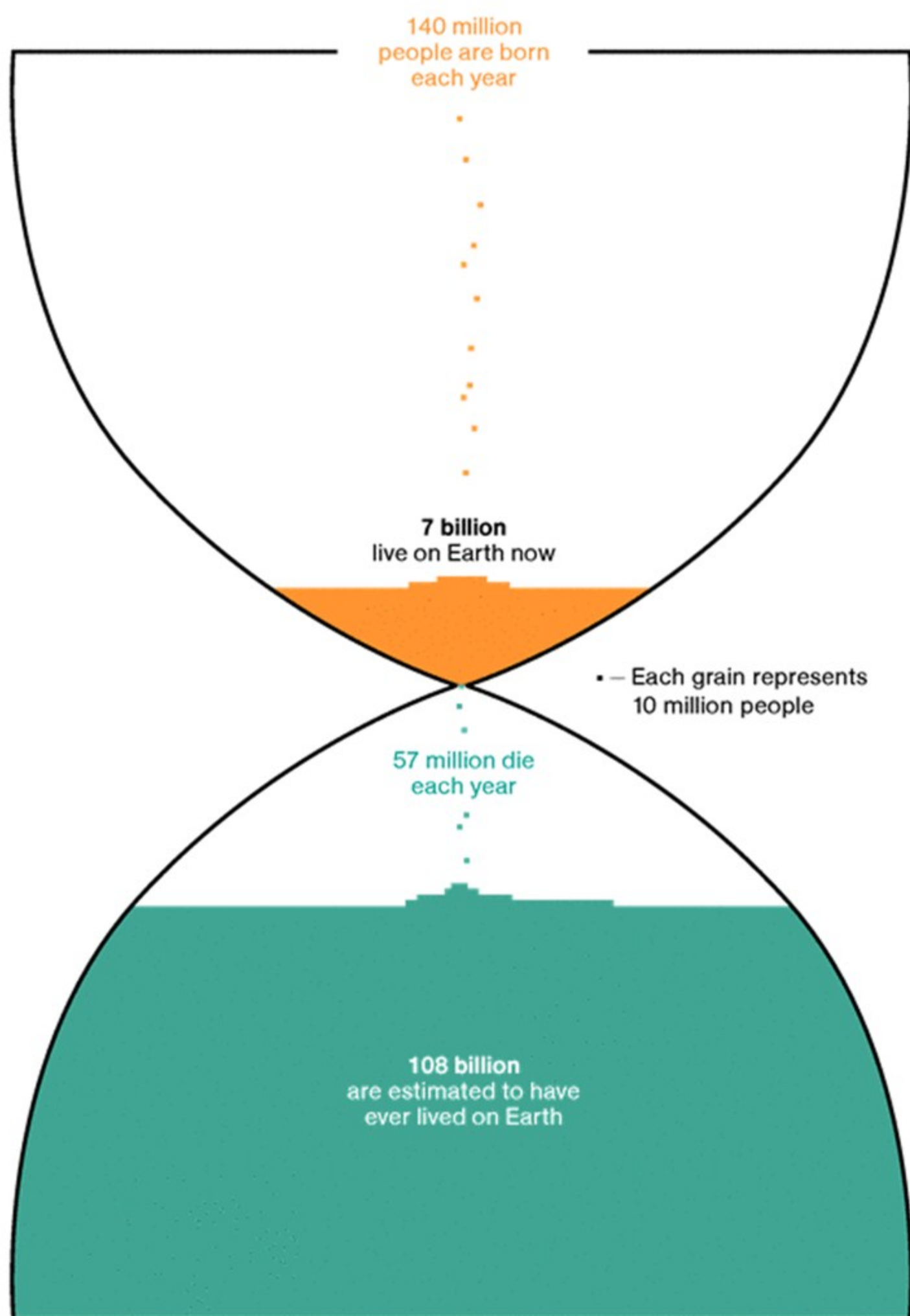
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Living It Up

Earth will soon be home to seven billion humans. If you find that hard to fathom, try grasping how many have ever walked the planet. That's what American demographer Carl Haub wanted to find out when, in 1975, he heard someone say that 75 percent of the

**7
SEVEN
BILLION**

people who'd ever been born were alive at that time. Dubious, he set out to disprove it, taking two main things into account: (1) the assumed dawn of humanity and (2) average populations at different periods of time.

Using 50,000 B.C. as his starting point, Haub applied crude birth-rates—the number of annual births per thousand people—to each population set, then added them. His estimate? In 1975, 103 billion people had lived, but only 4 percent of them were alive at that time. Applied to 2011, says Haub, those numbers are 108 billion, and 6.4 percent. Mind-boggling, indeed. —Catherine Zuckerman

THE LIST

Predictable Passwords

ATMs and online banking require passwords. So do email accounts and many websites. Security expert Mark Burnett says all these codes should be like personal secrets, yet obvious ones seem to prevail. The ten most common are below. See yours? Might be time for an upgrade. —CZ

1 123456

2 password

3 12345678

4 1234

5 **_____***

6 12345


7 dragon

8 qwerty

9 696969

10 mustang

*Not appropriate to publish in this magazine. Many popular passwords are vulgar.



Pillars at the temple of Göbekli Tepe in southern Turkey—11,600 years old and up to 18 feet tall—may represent priestly dancers at a gathering. Note the hands above the loincloth-draped belt on the figure in the foreground.

We used to think agriculture gave rise to cities and later to writing, art, and religion. Now the world's oldest temple suggests the urge to worship sparked civilization.

The Birth of RELIGION





It's likely no one lived at Göbekli Tepe, a religious sanctuary built by hunter-gatherers. Scientists have excavated less than a tenth of the site—enough to convey the awe it must have inspired 7,000 years before Stonehenge.





A snarling predator erupts from a five-ton piece of limestone, which artisans moved to Göbekli Tepe from a nearby quarry without the aid of draft animals or wheels.

By Charles C. Mann Photographs by Vincent J. Musi

EVERY NOW AND THEN THE DAWN OF CIVILIZATION IS REENACTED ON A REMOTE HILLTOP IN SOUTHERN TURKEY.

The reenactors are busloads of tourists—usually Turkish, sometimes European. The buses (white, air-conditioned, equipped with televisions) blunder over the winding, indifferently paved road to the ridge and dock like dreadnoughts before a stone portal. Visitors flood out, fumbling with water bottles and MP3 players. Guides call out instructions and explanations. Paying no attention, the visitors straggle up the hill. When they reach the top, their mouths flop open with amazement, making a line of perfect cartoon O's.

Before them are dozens of massive stone pillars arranged into a set of rings, one mashed up against the next. Known as Göbekli Tepe (pronounced Guh-behk-LEE TEH-peh), the site is vaguely reminiscent of Stonehenge, except that Göbekli Tepe was built much earlier and is made not from roughly hewn blocks but from cleanly carved limestone pillars splashed with bas-reliefs of animals—a cavalcade of gazelles, snakes, foxes, scorpions, and ferocious wild boars. The assemblage was built some 11,600 years ago, seven millennia before the Great Pyramid of Giza. It contains the oldest known temple. Indeed, Göbekli Tepe is the oldest known example of monumental architecture—the first structure human beings put together that was bigger and more complicated than a hut. When these pillars were erected, so far as we know, nothing of comparable scale existed in the world.

At the time of Göbekli Tepe's construction much of the human race lived in small nomadic bands that survived by foraging for plants and hunting wild animals. Construction of the site would have required more people coming together in one place than had likely occurred before. Amazingly, the temple's builders were able to cut, shape, and transport 16-ton stones hundreds of feet despite having no wheels or beasts of burden. The pilgrims who came to Göbekli Tepe lived in a world without writing, metal, or pottery; to those approaching the temple from below, its pillars must have loomed overhead like rigid giants, the animals on the stones shivering in the firelight—emissaries from a spiritual world that the human mind may have only begun to envision.

Archaeologists are still excavating Göbekli Tepe and debating its meaning. What they do know is that the site is the most significant in a volley of unexpected findings that have overturned earlier ideas about our species' deep past. Just 20 years ago most researchers believed they knew the time, place, and rough sequence of the Neolithic Revolution—the critical transition that resulted in the birth of agriculture, taking *Homo sapiens* from scattered groups of hunter-gatherers to farming villages and from there to technologically sophisticated societies with great temples and towers and kings and priests who directed the labor of their subjects

and recorded their feats in written form. But in recent years multiple new discoveries, Göbekli Tepe preeminent among them, have begun forcing archaeologists to reconsider.

At first the Neolithic Revolution was viewed as a single event—a sudden flash of genius—that occurred in a single location, Mesopotamia, between the Tigris and Euphrates Rivers in what is now southern Iraq, then spread to India, Europe, and beyond. Most archaeologists believed this sudden blossoming of civilization was driven largely by environmental changes: a gradual warming as the Ice Age ended that allowed some people to begin cultivating plants and herding animals in abundance. The new research suggests that the “revolution” was actually carried out by many hands across a huge area and over thousands of years. And it may have been driven not by the environment but by something else entirely.

After a moment of stunned quiet, tourists at the site busily snap pictures with cameras and cell phones. Eleven millennia ago nobody had digital imaging equipment, of course. Yet things have changed less than one might think. Most of the world’s great religious centers, past and present, have been destinations for pilgrimages—think of the Vatican, Mecca, Jerusalem, Bodh Gaya (where Buddha was enlightened), or Cahokia (the enormous Native American complex near St. Louis). They are monuments for spiritual travelers, who often came great distances, to gawk at and be stirred by. Göbekli Tepe may be the first of all of them, the beginning of a pattern. What it suggests, at least to the archaeologists working there, is that the human sense of the sacred—and the human love of a good spectacle—may have given rise to civilization itself.

Charles C. Mann’s new book, 1493: Uncovering the New World Columbus Created, is due out in August. Vincent J. Musi photographed the domestication of animals for our March issue.



Klaus Schmidt knew almost instantly that he was going to be spending a lot of time at Göbekli Tepe. Now a researcher at the German Archaeological Institute (DAI), Schmidt had spent the autumn of 1994 trundling across southeastern Turkey. He had been working at a site there for a few years and was looking for another place to excavate. The biggest city in the area is Şanlıurfa (pronounced shan-LYOOR-fa). By the standards of a brash newcomer like London, Şanlıurfa is incredibly old—the place

where the Prophet Abraham supposedly was born. Schmidt was in the city to find a place that would help him understand the Neolithic, a place that would make Şanlıurfa look young. North of Şanlıurfa the ground ripples into the first foothills of the mountains that run across

southern Turkey, source of the famous Tigris and Euphrates Rivers. Nine miles outside of town is a long ridge with a rounded crest that locals call Potbelly Hill—Göbekli Tepe.

In the 1960s archaeologists from the University of Chicago had surveyed the region and concluded that Göbekli Tepe was of little interest. Disturbance was evident at the top of the hill, but they attributed it to the activities of a Byzantine-era military outpost. Here and there were broken pieces of limestone they thought were gravestones. Schmidt had come across the Chicago researchers’ brief description of the hill-top and decided to check it out. On the ground he saw flint chips—huge numbers of them. “Within minutes of getting there,” Schmidt says, he realized that he was looking at a place where scores or even hundreds of people had worked in millennia past. The limestone slabs were not Byzantine graves but something much older. In collaboration with the DAI and the Şanlıurfa Museum, he set to work the next year.

Inches below the surface the team struck an elaborately fashioned stone. Then another, and another—a ring of standing pillars. As the months and years went by, Schmidt’s team, a shifting crew of German and Turkish graduate

students and 50 or more local villagers, found a second circle of stones, then a third, and then more. Geomagnetic surveys in 2003 revealed at least 20 rings piled together, higgledy-piggledy, under the earth.

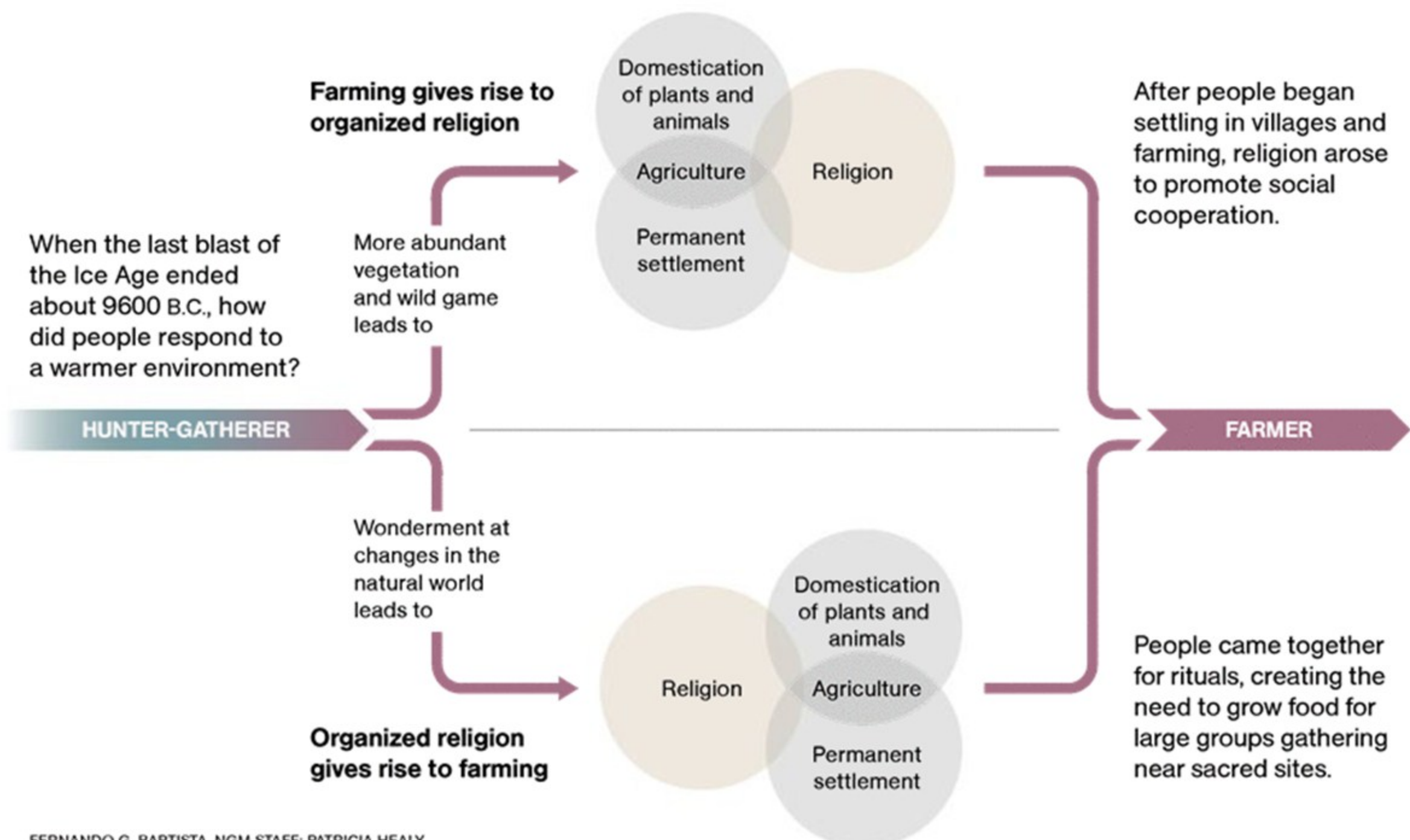
The pillars were big—the tallest are 18 feet in height and weigh 16 tons. Swarming over their surfaces was a menagerie of animal bas-reliefs, each in a different style, some roughly rendered, a few as refined and symbolic as Byzantine art. Other parts of the hill were littered with the greatest store of ancient flint tools Schmidt had ever seen—a Neolithic warehouse of knives, choppers, and projectile points. Even though the stone had to be lugged from neighboring valleys, Schmidt says, “there were more flints in one little area

here, a square meter or two, than many archaeologists find in entire sites.”

The circles follow a common design. All are made from limestone pillars shaped like giant spikes or capital T’s. Bladelike, the pillars are easily five times as wide as they are deep. They stand an arm span or more apart, interconnected by low stone walls. In the middle of each ring are two taller pillars, their thin ends mounted in shallow grooves cut into the floor. I asked German architect and civil engineer Eduard Knoll, who works with Schmidt to preserve the site, how well designed the mounting system was for the central pillars. “Not,” he said, shaking his head. “They hadn’t yet mastered engineering.” Knoll speculated that *(Continued on page 48)*

PATHS TO CIVILIZATION

Göbekli Tepe and other sites in the Middle East are changing ideas about how itinerant bands of hunter-gatherers settled into village life as farmers—a turning point in history called the Neolithic Revolution. Two theories about this transition, which unfolded over thousands of years, are outlined below.





FERNANDO G. BAPTISTA, NGM STAFF; PATRICIA HEALY
SOURCES: IAN KUIJT, UNIVERSITY OF NOTRE DAME; KLAUS SCHMIDT AND JENS NOTROFF, GERMAN ARCHAEOLOGICAL INSTITUTE; MELINDA A. ZEDER, SMITHSONIAN INSTITUTION


WHERE FARMING BEGAN


The Fertile Crescent was the heartland of the Neolithic Revolution. Göbekli Tepe sat on the northern edge of this region that curves along the boundary between mountain and desert, rich in the wild grasses and game that became the first domesticated grains and livestock. By 6000 B.C. the transformation from hunter-gatherers to farmers was largely complete in this area. As selected sites on the map show, this shift—whether driven by religious rituals, environmental changes, or population pressures—happened in different places and at different times.


KEY TO MAP AND GRAPHICS


 **Natufian culture**
(13,000-10,000 B.C.)


 **Pre-pottery Neolithic A**
(10,000-8500 B.C.)

 **Pre-pottery Neolithic B**
(8500-6250 B.C.)

 **Settlement**

 **Plant and animal domestication**

 **Monumental architecture** Large man-made structure of earth or stone

 **Ritual art** Symbolic representation of surroundings, such as animal carvings

Mediterranean

EGYPT

0 mi 100
0 km 100

Present-day boundaries, rivers, and shorelines shown

Nile

Wild wheat

Plumper kernels distinguish domesticated grains from their wild ancestors. Wild kernels drop off when ripe, but domesticated strains hold their kernels, allowing a more predictable harvest.

Domesticated wheat

Warm, wet climate

Cold, dry climate

NATUFIAN CULTURE

13,000 B.C.

12,000

11,000

The rise of village life

Early hunter-gatherer settlements—some with several hundred people—were largely abandoned when the warming climate chilled again for 1,200 years. About 9600 B.C. temperatures rose and villages rebounded, with people still foraging for most of their food and sharing it. As farming took hold and village populations increased, individual families fed themselves.

In Natufian settlements (named for a site where they were first excavated) hunter-gatherers built stacked-stone huts, probably roofed with animal hides.


18 people

Estimated average community size, based on studies in the southwest Fertile Crescent.

Communal area

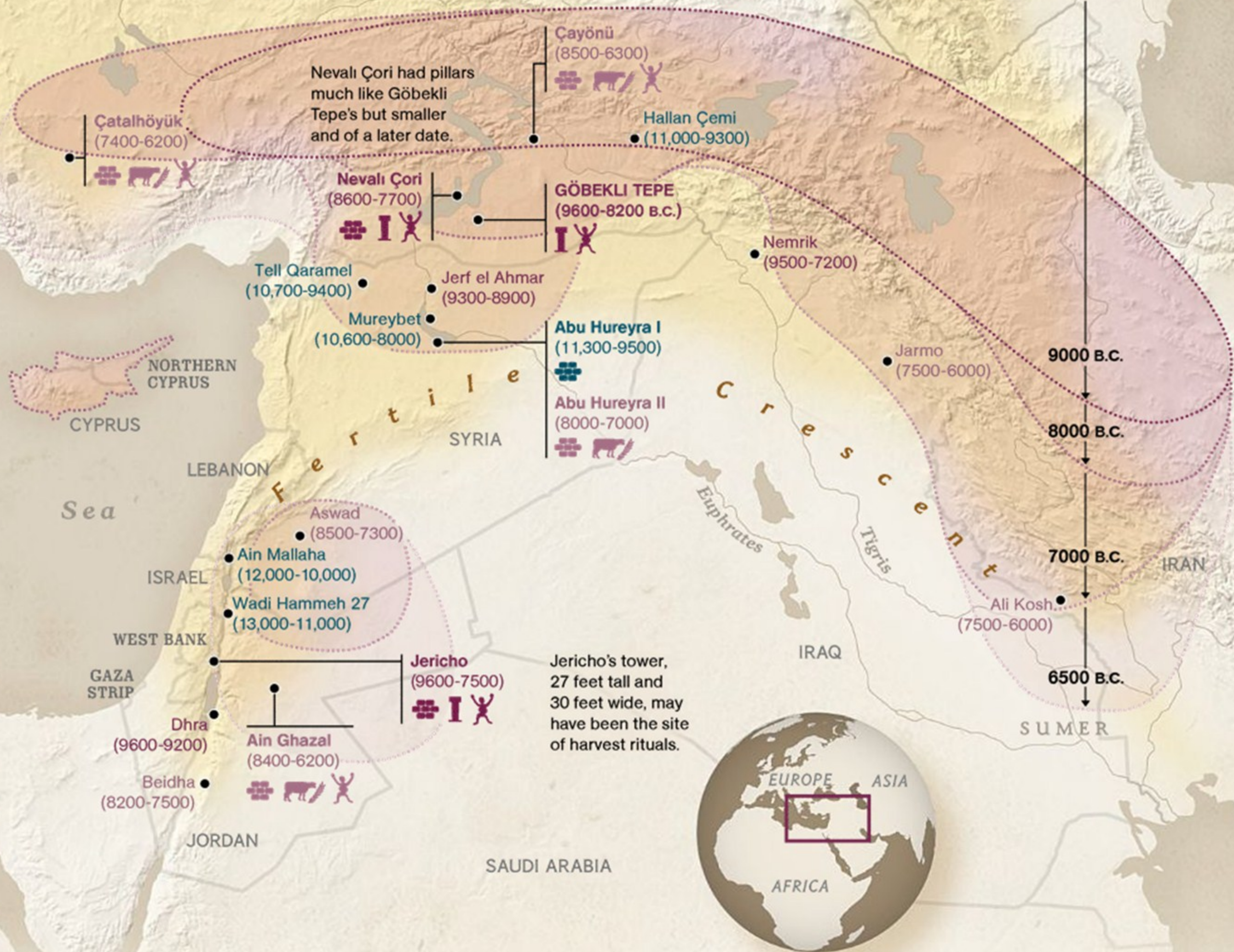
FERNANDO G. BAPTISTA, NGM STAFF; PATRICIA HEALY; DEBBIE GIBBONS, NG STAFF (MAP)

SOURCES: IAN KUJT, UNIVERSITY OF NOTRE DAME; KLAUS SCHMIDT, JENS NOTROFF, AND OLIVER DIETRICH, GERMAN ARCHAEOLOGICAL INSTITUTE; GEORGE WILLCOX, NATIONAL CENTER FOR SCIENTIFIC RESEARCH, FRANCE; MELINDA A. ZEDER, SMITHSONIAN INSTITUTION

Black Sea

Grain domestication
Present-day grain cultivation is shown; the range of wild grains is thought to have been slightly larger.

Animal domestication
Wild sheep and goats were the first livestock tamed, about 9000 B.C. Pigs then cattle followed in the next thousand years.



Warm, wetter climate

PRE-POTTERY NEOLITHIC A

10,000

9000

Villages of mud-brick huts included community food storage. Evidence of plant domestication is debated, but wild grains were cultivated.

90 people

PRE-POTTERY NEOLITHIC B

8000

7000

Thousands lived in farming villages of linked, multiroom homes. Interior walls displayed ritual symbols such as bull horns and skulls of ancestors.

900 people



BUILDING GÖBEKLI TEPE

People must have gathered from far-flung settlements to erect the first known temples. Using flint tools, they carved pillars and shaped blocks for walls mortared with clay. When a new temple was completed, the old one was buried. How the temples were used is unknown.

Head
Arm
Belt
Hands
Animal-skin loincloth

Carvings mark the pillars as stylized human figures, but did they represent powerful people or supernatural beings?

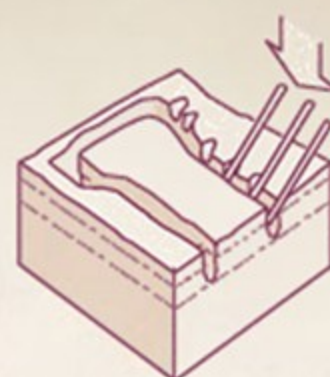
A pillar's shape was refined before being carved and placed.



- Pillars
- Excavated
- Unexcavated
- Area shown in illustration

Sanctuary grounds

Geomagnetic surveys of the 22-acre site suggest that at least 20 temples were built, from about 9600 to 8200 B.C. The oldest known are shown above.



Quarrying a pillar

The T-shape was incised directly into a bed of limestone. Pressure applied with levers then broke the rock along natural fracture lines, freeing the pillar.

Human muscle moved the limestone pillars, weighing up to 16 tons, from quarries as far as a quarter mile away.

The inner ring had no door and may have been accessed with ladders. Animal pelts may have hung on the pillars as offerings.

Offerings

Children may have helped by hauling rainwater collected in cisterns for drinking.

A sunken U-shaped block formed the entry pillars.

Spectator access?
Earthen embankments may have given pilgrims a view of ceremonies inside the rings. Or the temple may have been roofed and exclusive.

Possible roof

FERNANDO G. BAPTISTA (ART) AND LAWSON PARKER (MAP AND DIAGRAMS), NGM STAFF; PATRICIA HEALY
SOURCES: KLAUS SCHMIDT, JENS NOTROFF, AND OLIVER DIETRICH, GERMAN ARCHAEOLOGICAL INSTITUTE; IAN KUIJT, UNIVERSITY OF NOTRE DAME

*In southeastern Turkey some villagers
still harvest wheat with a sickle.
Einkorn wheat was first domesticated
here, perhaps to feed the crowds who
came to worship at Göbekli Tepe.*





(Continued from page 41) the pillars may have been propped up, perhaps by wooden posts.

To Schmidt, the T-shaped pillars are stylized human beings, an idea bolstered by the carved arms that angle from the “shoulders” of some pillars, hands reaching toward their loincloth-draped bellies. The stones face the center of the circle—as at “a meeting or dance,” Schmidt says—a representation, perhaps, of a religious ritual. As for the prancing, leaping animals on the figures, he noted that they are mostly deadly creatures: stinging scorpions, charging boars, ferocious lions. The figures represented by the pillars may be guarded by them, or appeasing them, or incorporating them as totems.

Puzzle piled upon puzzle as the excavation continued. For reasons yet unknown, the rings at Göbekli Tepe seem to have regularly lost their

Hundreds of people must have been required to carve and erect the pillars, but the site had no water source—the nearest stream was about three miles away. Those workers would have needed homes, but excavations have uncovered no sign of walls, hearths, or houses—no other buildings that Schmidt has interpreted as domestic. They would have had to be fed, but there is also no trace of agriculture. For that matter, Schmidt has found no mess kitchens or cooking fires. It was purely a ceremonial center. If anyone ever lived at this site, they were less its residents than its staff. To judge by the thousands of gazelle and aurochs bones found at the site, the workers seem to have been fed by constant shipments of game, brought from faraway hunts. All of this complex endeavor must have had organizers and overseers, but there is as yet no good evidence

of a social hierarchy—no living area reserved for richer people, no tombs filled with elite goods, no sign of some people having better diets than others.

“These people were foragers,” Schmidt says, people who gathered plants and hunted wild animals. “Our picture of foragers was always just small, mobile groups, a few dozen people.

They cannot make big permanent structures, we thought, because they must move around to follow the resources. They can’t maintain a separate class of priests and craft workers, because they can’t carry around all the extra supplies to feed them. Then here is Göbekli Tepe, and they obviously did that.”

Discovering that hunter-gatherers had constructed Göbekli Tepe was like finding that someone had built a 747 in a basement with an X-Acto knife. “I, my colleagues, we all thought, What? How?” Schmidt said. Paradoxically, Göbekli Tepe appeared to be both a harbinger of the civilized world that was to come and the last, greatest emblem of a nomadic past that was already disappearing. The accomplishment was astonishing, but it was hard to understand how it had been done or what it meant. “In 10

Göbekli totems

Animals carved on pillars at the site are native to the area and may represent guardian spirits.



power, or at least their charm. Every few decades people buried the pillars and put up new stones—a second, smaller ring, inside the first. Sometimes, later, they installed a third. Then the whole assemblage would be filled in with debris, and an entirely new circle created nearby. The site may have been built, filled in, and built again for centuries.

Bewilderingly, the people at Göbekli Tepe got steadily worse at temple building. The earliest rings are the biggest and most sophisticated, technically and artistically. As time went by, the pillars became smaller, simpler, and were mounted with less and less care. Finally the effort seems to have petered out altogether by 8200 B.C. Göbekli Tepe was all fall and no rise.

As important as what the researchers found was what they did not find: any sign of habitation.

or 15 years,” Schmidt predicts, “Göbekli Tepe will be more famous than Stonehenge. And for good reason.”

Hovering over Göbekli Tepe is the ghost of V. Gordon Childe. An Australian transplant to Britain, Childe was a flamboyant man, a passionate Marxist who wore plus fours and bow ties and larded his public addresses with noodle-headed paeans to Stalinism. He was also one of the most influential archaeologists of the past century. A great synthesist, Childe wove together his colleagues’ disconnected facts into overarching intellectual schemes. The most famous of these arose in the 1920s, when he invented the concept of the Neolithic Revolution.

In today’s terms, Childe’s views could be summed up like this: *Homo sapiens* burst onto the scene about 200,000 years ago. For most of the millennia that followed, the species changed remarkably little, with humans living as small bands of wandering foragers. Then came the Neolithic Revolution—“a radical change,” Childe said, “fraught with revolutionary consequences for the whole species.” In a lightning bolt of inspiration, one part of humankind turned its back on foraging and embraced agriculture. The adoption of farming, Childe argued, brought with it further transformations. To tend their fields, people had to stop wandering and move into permanent villages, where they developed new tools and created pottery. The Neolithic Revolution, in his view, was an explosively important event—“the greatest in human history after the mastery of fire.”

Of all the aspects of the revolution, agriculture was the most important. For thousands of years men and women with stone implements had wandered the landscape, cutting off heads of wild grain and taking them home. Even though these people may have tended and protected their grain patches, the plants they watched over were still wild. Wild wheat and barley, unlike their domesticated versions, shatter when they are ripe—the kernels easily break off the plant and fall to the ground, making them next to impossible to harvest when fully ripe. Genetically speaking, true grain agriculture

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began only when people planted large new areas with mutated plants that did not shatter at maturity, creating fields of domesticated wheat and barley that, so to speak, waited for farmers to harvest them.

Rather than having to comb through the landscape for food, people could now grow as much as they needed and where they needed it, so they could live together in larger groups. Population soared. “It was only after the revolution—but immediately thereafter—that our species really began to multiply at all fast,” Childe wrote. In these suddenly more populous societies, ideas could be more readily exchanged, and rates of technological and social innovation soared. Religion and art—the hallmarks of civilization—flourished.

Childe, like most researchers today, believed that the revolution first occurred in the Fertile Crescent, the arc of land that curves northeast from Gaza into southern Turkey and then sweeps southeast into Iraq. Bounded on the south by the harsh Syrian Desert and on the north by the mountains of Turkey, the crescent is a band of temperate climate between inhospitable extremes. Its eastern terminus is the confluence of the Tigris and Euphrates Rivers in southern Iraq—the site of a realm known as Sumer, which dates back to about 4000 B.C. In Childe’s day most researchers agreed that Sumer represented the beginning of civilization. Archaeologist Samuel Noah Kramer summed up that view in the 1950s in his book *History Begins at Sumer*. Yet even before Kramer finished writing, the picture was being revised at the opposite, western end of the Fertile Crescent. In the Levant—the area that today encompasses Israel, the (Continued on page 56)



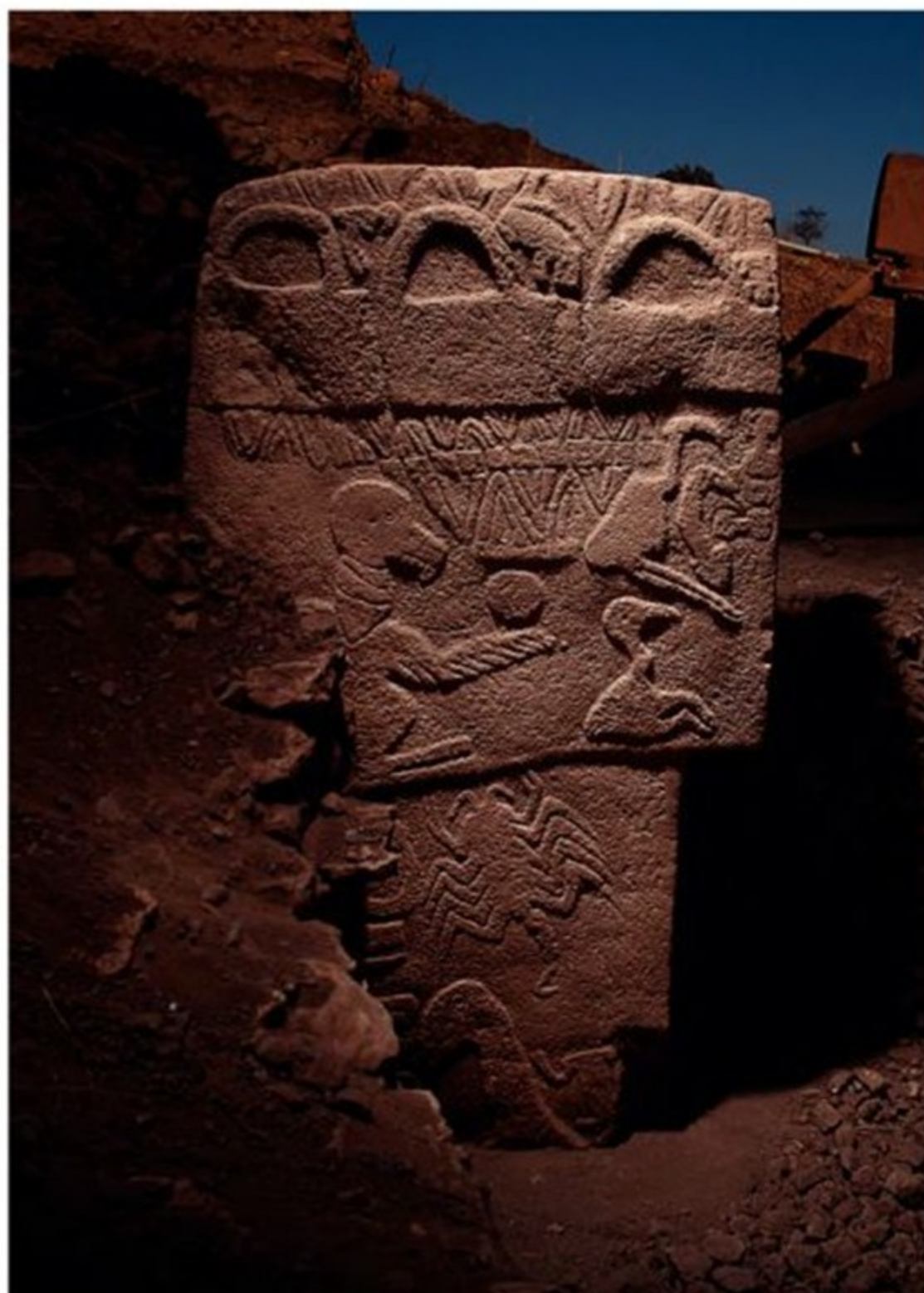
On a limestone bowl from Nevalı Çori, a settlement founded a thousand years after Göbekli Tepe, two figures dance with an animal. Perhaps guides to the spirit realm, animals were important symbols when humans began domesticating sheep, goats, and other beasts.



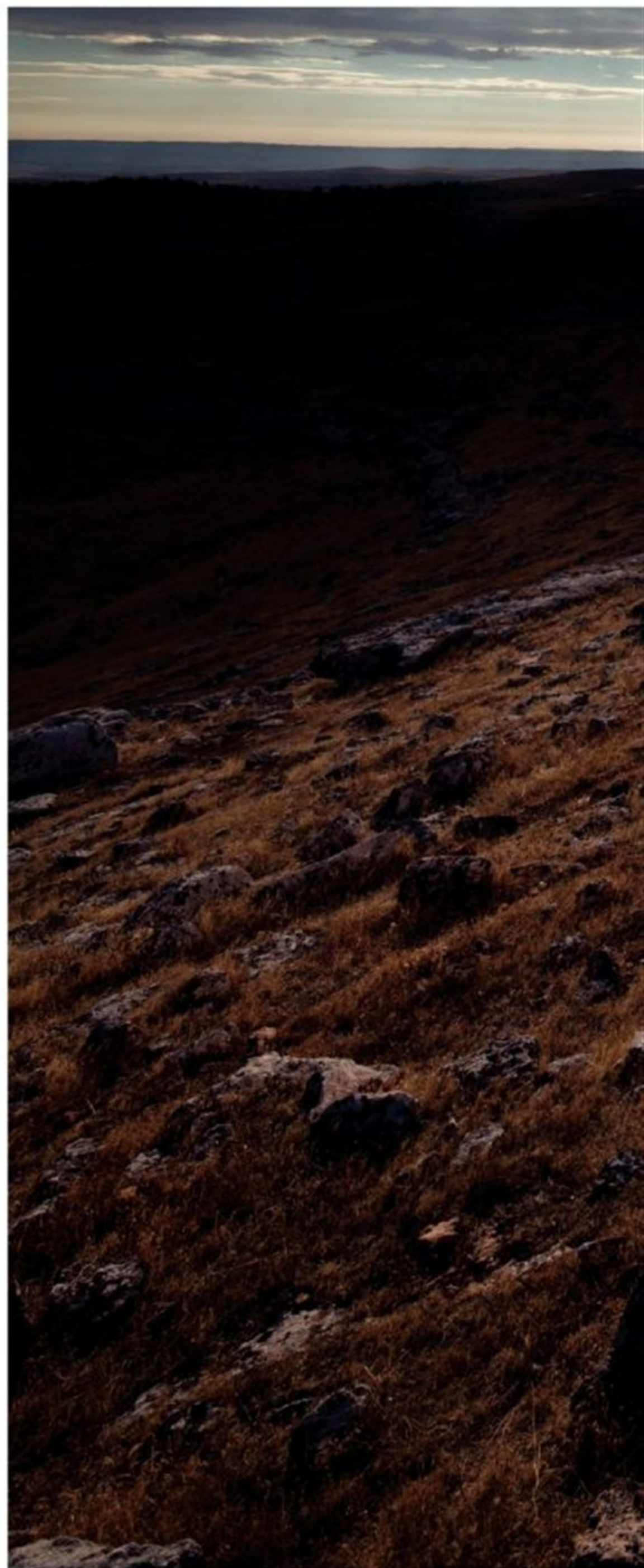


Clues to what may have been the world's first organized religion are scattered throughout Neolithic sites in southern Turkey, northern Syria, and Iraq. The most common icons were the dangerous beasts hovering outside humankind's newly formed settlements, including boars (below, from Göbekli Tepe) and snakes (right, on the back of a human head from Nevalı Çori). Though images of humans are rare, one dating to at least 8000 B.C. (left), discovered nine miles from Göbekli Tepe, is the earliest known life-size sculpture.





The elegant bas-reliefs of vultures, scorpions, and other creatures found on the T-shaped pillars had to have been created by skilled artisans, evidence that hunter-gatherers were capable of a complex social structure. Archaeologists have found a partially quarried pillar (right) in the limestone hills around Göbekli Tepe, which can be seen on the mound in the distance.





(Continued from page 49) Palestinian territories, Lebanon, Jordan, and western Syria—archaeologists had discovered settlements dating as far back as 13,000 B.C. Known as Natufian villages (the name comes from the first of these sites to be found), they sprang up across the Levant as the Ice Age was drawing to a close, ushering in a time when the region's climate became relatively warm and wet.

The discovery of the Natufians was the first rock through the window of Childe's Neolithic Revolution. Childe had thought agriculture the necessary spark that led to villages and ignited civilization. Yet although the Natufians lived in permanent settlements of up to several hundred people, they were foragers, not farmers, hunting gazelles and gathering wild rye, barley, and wheat. "It was a big sign that our ideas needed to be revised," says Harvard University archaeologist Ofer Bar-Yosef.

Natufian villages ran into hard times around 10,800 B.C., when regional temperatures abruptly fell some 12°F, part of a mini ice age that lasted 1,200 years and created much drier conditions across the Fertile Crescent. With animal habitat and grain patches shrinking, a number of villages suddenly became too populous for the local food supply. Many people once again became wandering foragers, searching the landscape for remaining food sources.

Some settlements tried to adjust to the more arid conditions. The village of Abu Hureyra, in what is now northern Syria, seemingly tried to cultivate local stands of rye, perhaps replanting them. After examining rye grains from the site, Gordon Hillman of University College London and Andrew Moore of the Rochester Institute of Technology argued in 2000 that some were bigger than their wild equivalents—a possible sign of domestication, because cultivation inevitably increases qualities, such as fruit and seed size, that people find valuable. Bar-Yosef and some other researchers came to believe that nearby sites like Mureybet and Tell Qaramel also had had agriculture.

If these archaeologists were correct, these proto-villages provided a new explanation of how

complex society began. Childe thought that agriculture came first, that it was the innovation that allowed humans to seize the opportunity of a rich new environment to extend their dominion over the natural world. The Natufian sites in the Levant suggested instead that settlement came first and that farming arose later, as a product of crisis. Confronted with a drying, cooling environment and growing populations, humans in the remaining fecund areas thought, as Bar-Yosef puts it, "If we move, these other folks will exploit our resources. The best way for us to survive is to settle down and exploit our own area." Agriculture followed.

The idea that the Neolithic Revolution was driven by climate change resonated during the 1990s, a time when people were increasingly worried about the effects of modern global warming. It was promoted in countless articles and books and ultimately enshrined in Wikipedia. Yet critics charged that the evidence was weak, not least because Abu Hureyra, Mureybet, and many other sites in northern Syria had been flooded by dams before they could be fully excavated. "You had an entire theory on the origins of human culture essentially based on a half a dozen unusually plump seeds," ancient-grain specialist George Willcox of the National Center for Scientific Research, in France, says. "Isn't it more likely that these grains were puffed during charring or that somebody at Abu Hureyra found some unusual-looking wild rye?"

As the dispute over the Natufians sharpened, Schmidt was carefully working at Göbekli Tepe. And what he was finding would, once again, force many researchers to reassess their ideas.

Anthropologists have assumed that organized religion began as a way of salving the tensions that inevitably arose when hunter-gatherers settled down, became farmers, and developed large societies. Compared to a nomadic band, the society of a village had longer term, more complex aims—storing grain and maintaining permanent homes. Villages would be more likely to accomplish those aims if their members were committed to the collective enterprise. Though primitive

religious practices—burying the dead, creating cave art and figurines—had emerged tens of thousands of years earlier, organized religion arose, in this view, only when a common vision of a celestial order was needed to bind together these big, new, fragile groups of humankind. It could also have helped justify the social hierarchy that emerged in a more complex society: Those who rose to power were seen as having a special connection with the gods. Communities of the faithful, united in a common view of the world and their place in it, were more cohesive than ordinary clumps of quarreling people.

Göbekli Tepe, to Schmidt's way of thinking, suggests a reversal of that scenario: The construction of a massive temple by a group of foragers is evidence that organized religion could have come *before* the rise of agriculture and other aspects of civilization. It suggests that the human impulse to gather for sacred rituals arose as humans shifted from seeing themselves as part of the natural world to seeking mastery over it. When foragers began settling down in villages, they unavoidably created a divide between the human realm—a fixed huddle of homes with hundreds of inhabitants—and the dangerous land beyond the campfire, populated by lethal beasts.

French archaeologist Jacques Cauvin believed this change in consciousness was a “revolution of symbols,” a conceptual shift that allowed humans to imagine gods—supernatural beings resembling humans—that existed in a universe beyond the physical world. Schmidt sees Göbekli Tepe as evidence for Cauvin's theory. “The animals were guardians to the spirit world,” he says. “The reliefs on the T-shaped pillars illustrate that other world.”

Schmidt speculates that foragers living within a hundred-mile radius of Göbekli Tepe created the temple as a holy place to gather and meet, perhaps bringing gifts and tributes to its priests and craftspeople. Some kind of social organization would have been necessary not only to build it but also to deal with the crowds it attracted. One imagines chanting and drumming, the animals on the great pillars seeming to move in flickering torchlight.

Göbekli Tepe
MAY HAVE BEEN A
HOLY PLACE FOR
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IT MAY ALSO HAVE
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Surely there were feasts; Schmidt has uncovered stone basins that could have been used for beer. The temple was a spiritual locus, but it may also have been the Neolithic version of Disneyland.

Over time, Schmidt believes, the need to acquire sufficient food for those who worked and gathered for ceremonies at Göbekli Tepe may have led to the intensive cultivation of wild cereals and the creation of some of the first domestic strains. Indeed, scientists now believe that one center of agriculture arose in southern Turkey—well within trekking distance of Göbekli Tepe—at exactly the time the temple was at its height. Today the closest known wild ancestors of modern einkorn wheat are found on the slopes of Karaca Dağ, a mountain just 60 miles northeast of Göbekli Tepe. In other words, the turn to agriculture celebrated by V. Gordon Childe may have been the result of a need that runs deep in the human psyche, a hunger that still moves people today to travel the globe in search of awe-inspiring sights.

Some of the first evidence for plant domestication comes from Nevalı Çori (pronounced nuh-vah-LUH CHO-ree), a settlement in the mountains scarcely 20 miles away. Like Göbekli Tepe, Nevalı Çori came into existence right after the mini ice age, a time archaeologists describe with the unlovely term Pre-pottery Neolithic (PPN). Nevalı Çori is now inundated by a recently created lake that provides electricity and irrigation water for the region. But before the waters shut down research, archaeologists found T-shaped pillars and animal images much like those Schmidt would later uncover at Göbekli

Tepe. Similar pillars and images occurred in PPN settlements up to a hundred miles from Göbekli Tepe. Much as one can surmise today that homes with images of the Virgin Mary belong to Christians, Schmidt says, the imagery in these PPN sites indicates a shared religion—a community of faith that surrounded Göbekli Tepe and may have been the world's first truly large religious grouping.

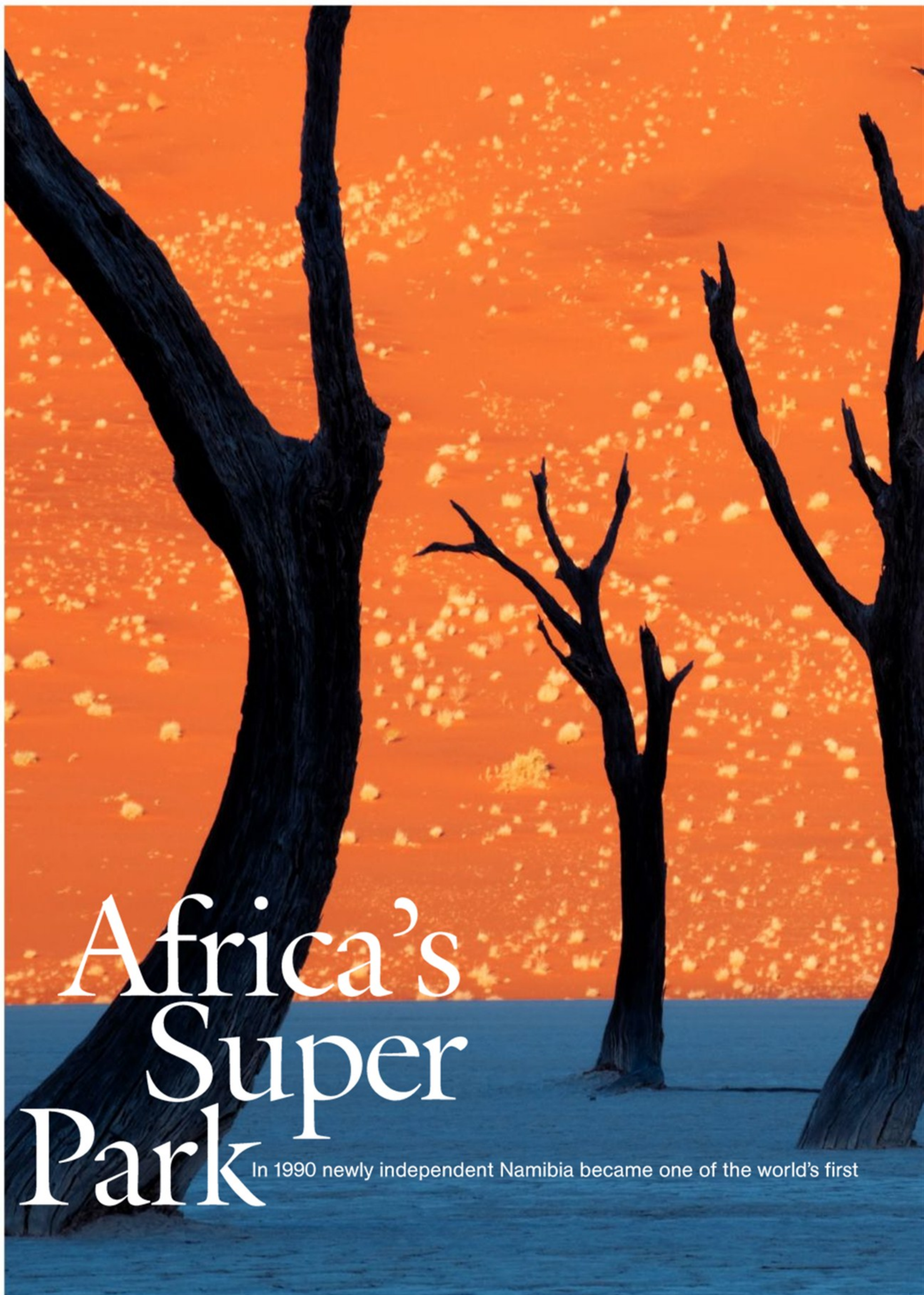
Naturally, some of Schmidt's colleagues disagree with his ideas. The lack of evidence of houses, for instance, doesn't prove that nobody lived at Göbekli Tepe. And increasingly, archaeologists studying the origins of civilization in the Fertile Crescent are suspicious of any attempt to find a one-size-fits-all scenario, to single out one primary trigger. It is more as if the occupants of various archaeological sites were all playing with the building blocks of civilization, looking for combinations that worked. In one place agriculture may have been the foundation; in another, art and religion; and over there, population pressures or social organization and hierarchy. Eventually they all ended up in the same place. Perhaps there is no single path to civilization; instead it was arrived at by different means in different places.

In Schmidt's view, many of his colleagues have been as slow to appreciate Göbekli Tepe as he has been to excavate it. This summer will mark his 17th year at the site. The annals of archaeology are replete with scientists who in their hurry carelessly wrecked important finds, losing knowledge for all time. Schmidt is determined not to add his name to the list. Today less than a tenth of the 22-acre site is open to the sky.

Schmidt emphasizes that further research on Göbekli Tepe may change his current understanding of the site's importance. Even its age is not clear—Schmidt is not certain he has reached the bottom layer. "We come up with two new mysteries for every one that we solve," he says. Still, he has already drawn some conclusions. "Twenty years ago everyone believed civilization was driven by ecological forces," Schmidt says. "I think what we are learning is that civilization is a product of the human mind." □



A pillar with a carved, elongated fox stands against the starry night. To protect the fragile reliefs, archaeologists plan to construct a roof over the site this year. Pondering the mysteries of this ancient temple under an open sky will soon be a thing of the past.



Africa's Super Park

In 1990 newly independent Namibia became one of the world's first



nations to write environmental protection into its constitution.



A brown hyena carries off a dead fur seal pup in Sperrgebiet National Park, as a jackal looks on. These reclusive hyenas, numbering fewer than 1,200 in Namibia and 8,000 Africa-wide, have rarely been photographed. Proclaimed in 2008, the park—whose name means “forbidden area” in German—corresponds to a diamond-mining lease long off-limits to the public.







Pink flamingos mass on the water in Sandwich Harbour. Once a secluded anchorage for whalers, this desolate lagoon in Namib-Naukluft Park is now renowned for its birdlife, with more than a hundred species recorded.



t dawn, three weeks before the winter solstice, the last tendrils of fog curled gray against the pinking sky over a sand dune on the eastern edge of the Namib Desert. A jackal trotted west toward a stand of camel thorn trees. An oryx cruised doggedly toward a water hole at a nearby tourist camp. A tenebrionid beetle scuttled shiny black on the red sand, leaving perfect beetle tracks in

its wake. Next to me was Rudolph !Naibab,* a safari guide who grew up on recalcitrant earth in the Kunene region, roughly 300 miles north of this spot in the NamibRand Nature Reserve, raising sheep, goats, and donkeys on his grandmother's farm.

!Naibab is 30, but he has a much older man's acumen, something he attributes to being raised in the desert. "This land makes you consider life and death every day," he said. "And war. I was raised during war. That can also make you wise in a hurry."

Namibia's civil war started in 1966 and lasted 22 years. In 1990, when Namibia at last gained independence from South Africa, it was one of the first countries in the world to write protection of the environment into its constitution. It was as if Namibians recognized that having fought for the land beneath their feet, they were now profoundly responsible for it.

"I think there were many reasons that Namibia's ecomovement was born at independence," !Naibab said. "During the war, in the mid-1980s, there was also a drought, and farmers were getting desperate. Their sheep died, so they started to kill game. It was easy for Namibians to see how close to dying we can get unless we protect and respect the resources we have."

Until 20 or so years ago all this land, and the land next door, and the land beyond that, was fenced and stocked with sheep. I tried to imagine those sheep farmers with their backs to the wind, buried under oxide red sand, waiting years for rain. "Yes, I am sure those sheep farmers had mixed feelings about this place," !Naibab agreed. "On the one hand, no water. On the other hand, how can you not be in awe of this place? How could you not feel a responsibility to guard it?"

I had come to Namibia because in late 2008 the government had proclaimed 5.4 million

acres of its southwest coastline as Sperrgebiet National Park. With this, officials could say that nearly half the country's landmass was given over to national parks, communal conservancies, and private wilderness reserves. With the creation of Dorob National Park in December 2010, the coastline from the Kunene River on the Angolan border to the Orange River on the South African border was an almost solid barrier of parks. All the pieces were in place for what may eventually be designated Namib-Skeleton Coast National Park—a single coastal megapark. Namibia seemed a rare, almost impossibly hopeful story of a young African democracy determined to be a leading example of land stewardship.

This optimism seemed well-founded on my second day in the country, when I arrived in the Kulala Wilderness, a 91,400-acre refuge adjacent to the NamibRand Nature Reserve. It was the very day of the scheduled release of two cheetahs by one of Namibia's most celebrated conservationists, Marlice van Vuuren, and her husband, Rudie. Raised among Bushmen in the Omaheke region of Namibia, Marlice can speak their language fluently, one of the few non-Bushmen able to do so. Now in her early 30s, she runs N/a'an Ku Sê, a game sanctuary 25 miles east of Windhoek, where with the help of Bushmen trackers she rehabilitates orphaned and injured wildlife, relocating the animals from areas where there is conflict with humans to areas where humans, in the form of tourists, are likely to pay good money to see them.

The repair and restocking of wild lands is not easy or free. "It takes a massive amount of planning and effort to reestablish balance in a habitat to the point you can bring cheetahs back," Marlice said. "Everything has to be in place. Is there sufficient prey? Is there water? Is this sustainable? If the answers to those questions are

*The ! before Naibab is one of the notations for click sounds in the local languages.



Desert-dwelling elephants follow the contours of the ancient Huab River Valley, wending through the timeless landscapes of the Torra Conservancy, one of some 60 such areas overseen by local communities.

yes, that's half the battle. And then we just have to wait and see if the cheetahs like where we put them." The two cheetahs snarled and refused to get out of their trailer. The male bit Rudie on the foot. So we backed away and waited. An unremarkable shrub on the gravel plain moved and resolved into an ostrich. We waited some more. The wind did its best to blow right through us.

People who live in and near the Namib Desert speak of two winds: the east wind that blows in from the Kalahari, gaining strength as it loses altitude until it hits this desert at 60 miles an hour and raises temperatures to 100 degrees Fahrenheit or more. And the life-sustaining southwesterly wind from the cold Atlantic that blows fog as much as 40 miles inland, providing almost all the moisture needed to sustain the shape-shifting wildlife here. It is not an extravagant living, this fog-fed existence, for snakes and lizards, beetles and spiders, but it's an impressively specialized one.

It is also a fragile living, so much so that some Namibians I spoke to worried that the slightest shift of climate could send the whole

delicate system into collapse. "It's hard not to imagine that a few degrees warmer would be catastrophic. This is a climate and an ecosystem already so extreme," said Conrad Brain, a wildlife veterinarian who had come to keep an eye on the cheetahs' release. Brain, who is also a pilot, flies frequently up and down the Namibian coast and keeps a careful, if somewhat anecdotal, eye on climate trends. "We've seen jellyfish swarms, shark swarms, leatherback turtles coming too far south—those are all indications to me that the sea is warming," he said. "It's easy to feel a bit alarmed. That's why this—releasing these cheetahs—gives you a feeling of possibility and hope." We stopped talking and went back to watching the trailer. Time did what it does in the desert: It expanded with the heat.

Just as I'd put my notebook away, the cheetahs suddenly left the trailer. First the female decanted

Alexandra Fuller's book Cocktail Hour Under the Tree of Forgetfulness will be published in August. Frans Lanting has documented nature and wildlife throughout Africa for more than 25 years.

onto the ground. Then the male poured after her. Within seconds they were gone from our sight, even if we were not gone from theirs.

The successful relocation of these two cheetahs represents a trend in Namibia. Wildlife numbers are increasing, especially in conservancies and private reserves beyond national park boundaries. In the 1980s there were at most 10,000 springbok in the north; now there are an estimated 160,000. By 1990 black rhinos had been hunted to the brink of extinction in Namibia; now there are more than 1,400. Twenty years ago some 800 cheetahs were shot every year by farmers; now approximately 150 are killed by ranchers and farmers, and trophy hunters are permitted to shoot 150.

TO REACH SPERRGEBIET, I flew almost the entire extent of the Namib Desert at its broadest point (from the NamibRand Nature Reserve to Walvis Bay), and then a fairly decent chunk of its length (from Walvis Bay to Lüderitz). The journey to and through the park was at least as striking for the contradictions it exposed as for its demonstration of remote, wind-scoured beauty. Although the landscape manifested itself mostly as pure topography—dunes and the glittering quartz in Witberg mountain—the scars of human activity from a century ago were still evident: abandoned diamond camps holding out against the wind, sun, and sand. (Closer to Walvis Bay, the desert bore a new imprint—the mindless doodles of thousands of all-terrain vehicles, which had churned the fragile encrusted surface.)

For the most part Westerners had ignored Namibia and its forbiddingly arid conditions—“the land God made in anger,” as some called it. But this did not exempt Namibia from the frenzied exploitation going on in the rest of Africa. The islands offshore (now proclaimed a marine sanctuary as part of the overall protection of the coast) were raked for nitrogen-rich guano, used in the manufacture of gunpowder and fertilizer, and the cold, nutrient-rich Atlantic waters were scoured for whales. By the early 1900s guano deposits tens of feet deep had been scraped to

bare rock, and southern right whales had been hunted almost out of existence.

In 1908 the first diamond was spotted in the south. Within months the German government, which held South-West Africa—present-day Namibia—as a protectorate, designated the 5.4 million acres surrounding that discovery as the Sperrgebiet (“forbidden area”), accessible only to the diamond company and its miners. To overcome the shortage of workers created by the German colonists’ cataclysmic war against southern peoples (the Herero, Nama, and Damara), laborers were conscripted from remote northern tribes (the Ovambo and Kavango) who had not been involved in the war. To this day, mounds resembling children’s graves can be seen all across the Sperrgebiet, an inadvertent memorial to the labor of those men who crawled across the desert sifting the gravel and picking out diamonds stone by stone.

Diamond mining continues along the shore in the southern part of the new park, and from the air the excavations show up as massive trenches. Although the mining areas are strictly off-limits to unauthorized visitors, fear of illegal mining and thieving means that the whole of the Sperrgebiet still feels forbidden—not so much protected as jealously guarded. Only a few tourists may enter the park at a time, with a pre-approved guide, and roadside cameras monitor traffic entering and leaving the park. The prevailing atmosphere of paranoia is perhaps best illustrated by the rusting and sunbaked vehicles and equipment abandoned within the park when no longer useful—an attempt to prevent mine workers from stashing diamonds in machinery to be retrieved later in some junkyard.

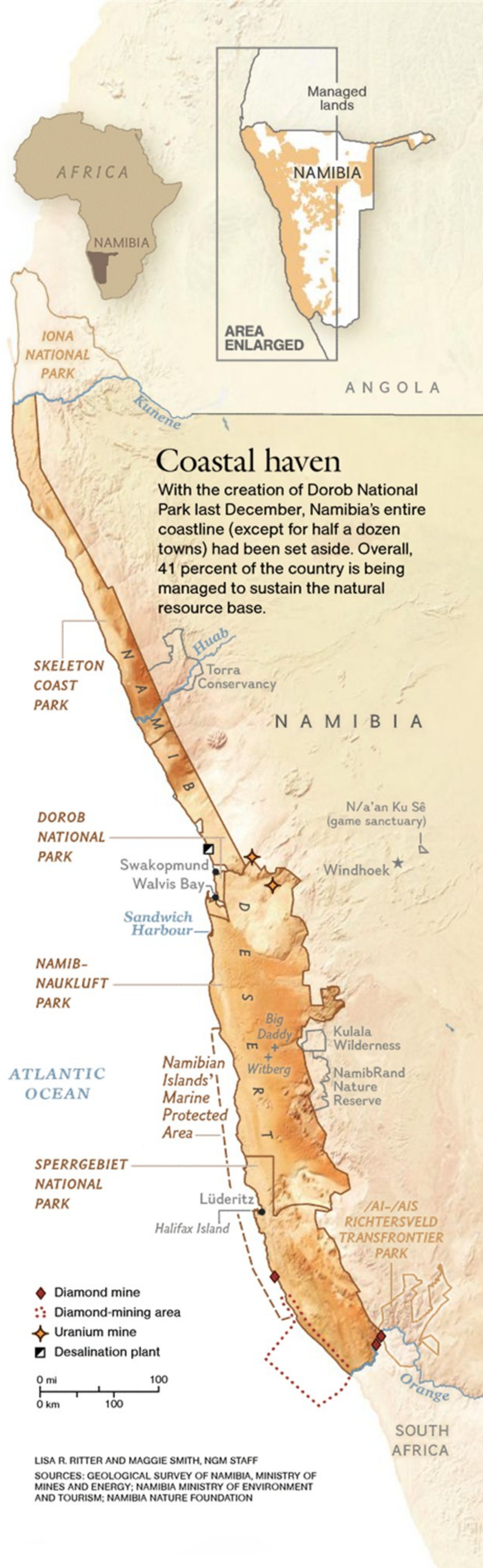
Namibia is now the fourth largest exporter of nonfuel minerals in Africa and the world’s fourth largest producer of uranium. That mineral wealth doesn’t trickle down in any real sense—Namibia has one of the most unequal income distributions in the world—and the pursuit of it occurs not only on private land but also in and around areas that have been set aside as national parks. Two mines, one of which is within Namib-Naukluft Park, are now producing

uranium; output is expected to rise from 12 million pounds of yellowcake to around 40 million pounds by 2015. It's a striking irony that to extract its plentiful uranium, Namibia must use quantities of a very scarce resource: water. Figures are not easy to come by, but one mine uses 106 million cubic feet of water a year. At the time of my visit the water was taken from aquifers—fossil water that is not adequately replenished by Namibia's scant rainfall—although a massive new desalination plant was being built on the coast near Swakopmund.

In theory, mining is supposed to occur in concert with resource protection and economic development. "We're a developing nation," explained Midori Paxton, who then worked for the Ministry of Environment and Tourism in Windhoek. "It's not realistic to exclude mining from our protected areas, but we work hard to minimize the impact of the mining," she said, showing me a map of biodiversity hot spots identified by the ministry. "We work closely with the mining companies to identify and protect these very sensitive areas." She indicated an area now in Dorob National Park that is one of the most important lichen fields in the country.

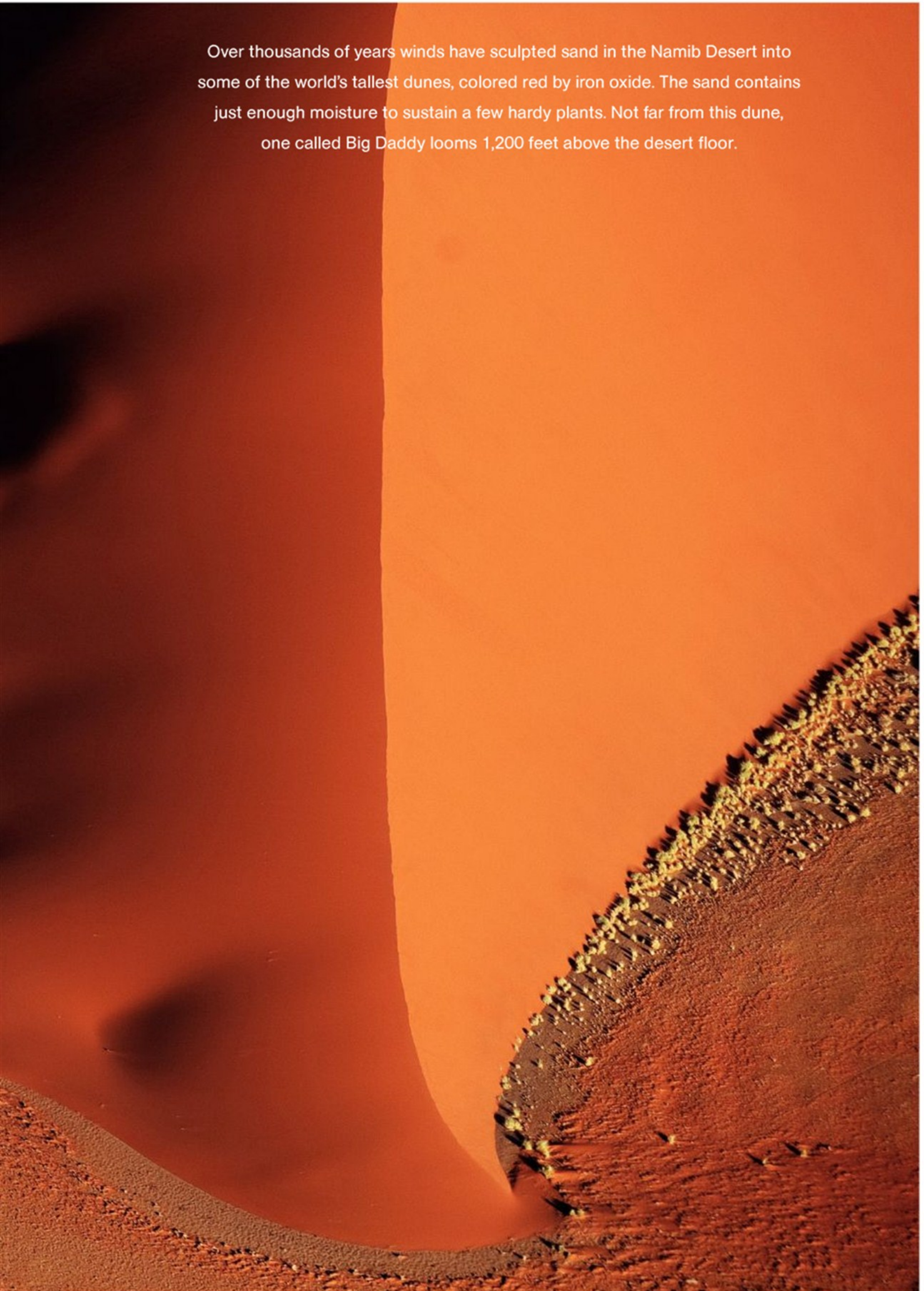
Lichen fields—blooms of orange and gray over red sand and crusts of blackish gypsum—keep the soil stable and are a critical source of food for invertebrates. They're the desert's building blocks for larger communities of plants and animals. In recognition of their vulnerability, the lichen fields have been marked off on maps and with fences. But the lichen field Paxton had pointed out on the map was between the sea and a uranium mine, and when I went there, it had recently been torn up. Prospecting trenches crossed the field not far from where the desalination plant was going up. Tracks from heavy trucks and four-by-fours tore deep into the ground, a carelessness that could take hundreds of years for the desert's slow systems to repair.

In the end it will be here, on the ancient surface of its protected lands—not in the tourist literature or official mining guidelines—that the strength and sincerity of Namibia's environmental intentions will be written. □





Over thousands of years winds have sculpted sand in the Namib Desert into some of the world's tallest dunes, colored red by iron oxide. The sand contains just enough moisture to sustain a few hardy plants. Not far from this dune, one called Big Daddy looms 1,200 feet above the desert floor.





Quiver trees (above) stand like eerie sentinels under the stars in the Namib Desert. The flowers of these desert-tough varieties of the aloe plant provide nectar for birds and insects. A water hole (right) in NamibRand Nature Reserve teems with birds such as these sandgrouse.





A waddle of African penguins shelters in a deserted hut on Halifax Island, part of a marine sanctuary off Sperrgebiet National Park. By the 1900s traders had stripped the guano penguins hid their eggs in, and the birds have had to lay them on bare ground, exposed to scavengers. Fewer than 30,000 breeding pairs now exist in the world.

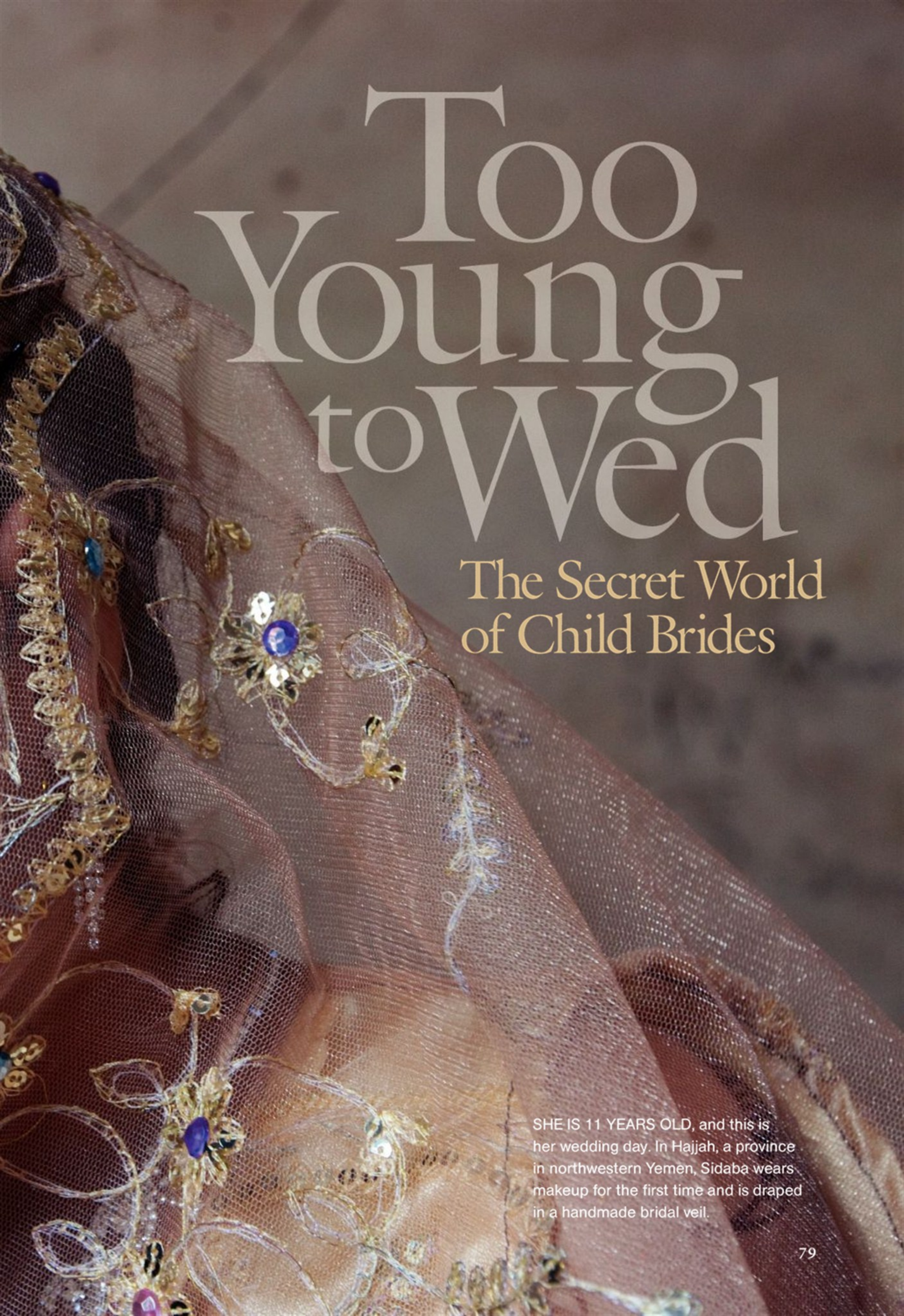




The markings of a Namaqua chameleon (above) match the sand in Sperrgebiet National Park, confusing predators. Tracks in the sand (right) belong to a pair of oryx, desert antelope that along with Namibia's other wildlife benefit from the country's generous allocation of protected areas.







Too Young to Wed

The Secret World of Child Brides

SHE IS 11 YEARS OLD, and this is her wedding day. In Hajjah, a province in northwestern Yemen, Sidaba wears makeup for the first time and is draped in a handmade bridal veil.

"Whenever I saw him, I hid. I hated to see him," Tahani (in pink) recalls of the early days of her marriage to Majed, when she was 6 and he was 25. The young wife, now 8, posed for a portrait with former classmate Ghada, also a child bride, outside their home in Hajjah.





BY CYNTHIA GORNEY

PHOTOGRAPHS BY STEPHANIE SINCLAIR

BECAUSE THE WEDDING WAS ILLEGAL AND A SECRET, except to the invited guests, and because marriage rites in Rajasthan are often conducted late at night, it was well into the afternoon before the three girl brides in this dry farm settlement in the north of India began to prepare themselves for their sacred vows. They squatted side by side on the dirt, a crowd of village women holding sari cloth around them as a makeshift curtain, and poured soapy water

from a metal pan over their heads. Two of the brides, the sisters Radha and Gora, were 15 and 13, old enough to understand what was happening. The third, their niece Rajani, was 5. She wore a pink T-shirt with a butterfly design on the shoulder. A grown-up helped her pull it off to bathe.

The grooms were en route from their own village, many miles away. No one could afford an elephant or the lavishly saddled horses that would have been ceremonially correct for the grooms' entrance to the wedding, so they were coming by car and were expected to arrive high-spirited and drunk. The only local person to have met the grooms was the father of the two oldest girls, a slender gray-haired farmer with a straight back and a drooping mustache. This farmer, whom I will call Mr. M, was both proud and wary as he surveyed guests funneling up the rocky path toward the bright silks draped over poles for shade; he knew that if a nonbribeable police officer found out what was under way, the wedding might be interrupted mid-ceremony, bringing criminal arrests and lingering shame to his family.

Rajani was Mr. M's granddaughter, the child of his oldest married daughter. She had round brown eyes, a broad little nose, and skin the color of milk chocolate. She lived with her grandparents. Her mother had moved to her husband's village, as rural married Indian women are expected to do, and this husband, Rajani's father, was rumored to be a drinker and a bad farmer.

The villagers said it was the grandfather, Mr. M, who loved Rajani most; you could see this in the way he had arranged a groom for her from the respectable family into which her aunt Radha was also being married. This way she would not be lonely after her *gauna*, the Indian ceremony that marks the physical transfer of a bride from her childhood family to her husband's. When Indian girls are married as children, the *gauna* is supposed to take place after puberty, so Rajani would live for a few more years with her grandparents—and Mr. M had done well to protect this child in the meantime, the villagers said, by marking her publicly as married.

These were things we learned in a Rajasthan village during Akha Teej, a festival that takes place during the hottest months of spring, just before the monsoon rains, and that is considered an auspicious time for weddings. We stared miserably at the 5-year-old Rajani as it became clear that the small girl in the T-shirt, padding around barefoot and holding the pink plastic sunglasses someone had given her, was also to be one of the midnight ceremony's brides. The man who had led us to the village, a cousin to Mr. M,

In Yemen marriage can resemble a business transaction. Sisters Sidaba (middle) and Galiyaah, 13 (left), married the brothers of their cousin, Khawlah, 12 (right). Khawlah wed the sisters' uncle.





A photograph showing two women, identified as Yemeni brides, walking down a steep, rocky path. They are both wearing black traditional dresses (thobes) and headscarves (hijabs). The woman on the right is also wearing a white headscarf and has a red flower pinned to her chest. The path is made of dirt and stones, and the surrounding area is covered in dense green vegetation. The text is overlaid in the upper right corner.

After celebrating with female relatives at a wedding party, Yemeni brides Sidaba and Galiyaah are veiled and escorted to a new life with their husbands. "Some rural girls see marriage as saving themselves from the control of their families," says an activist in the capital, Sanaa.



had advised us only that a wedding was planned for two teenage sisters. That in itself was risky to disclose, as in India girls may not legally marry before age 18. But the techniques used to encourage the overlooking of illegal weddings—neighborly conspiracy, appeals to family honor—are more easily managed when the betrothed girls have at least reached puberty. The littlest daughters tend to be added on discreetly, their names kept off the invitations, the unannounced second or third bride at their own weddings.

Cynthia Gorney is a contributing writer for the magazine. Stephanie Sinclair has documented the global issue of child marriage for nearly a decade. The photographs from India were supported by the Alexia Foundation.

Rajani fell asleep before the ceremonials began. An uncle lifted her gently from her cot, hoisted her over one of his shoulders, and carried her in the moonlight toward the Hindu priest and the smoke of the sacred fire and the guests on plastic chairs and her future husband, a ten-year-old boy with a golden turban on his head.

THE OUTSIDER'S IMPULSE toward child bride rescue scenarios can be overwhelming: Snatch up the girl, punch out the nearby adults, and run. Just make it stop. Above my desk, I have taped to the wall a photograph of Rajani on her wedding night. In the picture it's dusk, six hours before the marriage ceremony, and her face is turned toward the camera, her eyes wide and untroubled, with the beginnings of a smile. I remember



Asia, a 14-year-old mother, washes her new baby girl at home in Hajjah while her 2-year-old daughter plays. Asia is still bleeding and ill from childbirth yet has no education or access to information on how to care for herself.

The outsider's impulse toward child bride rescue scenarios can be overwhelming: Snatch up the girl, punch out the nearby adults, and run. Just make it stop.

my own rescue fantasies roiling that night—not solely for Rajani, whom I could have slung over my own shoulder and carried away alone, but also for the 13- and the 15-year-old sisters who were being transferred like requisitioned goods, one family to another, because a group of adult males had arranged their futures for them.

The people who work full-time trying to prevent child marriage, and to improve women's lives in societies of rigid tradition, are the first to smack down the impertinent notion that anything about this endeavor is simple. Forced early marriage thrives to this day in many regions of the world—arranged by parents for their own children, often in defiance of national laws, and understood by whole communities as an appropriate way for a young woman to grow up when the alternatives, especially if they carry a risk of her losing her virginity to someone besides her husband, are unacceptable.

Child marriage spans continents, language, religion, caste. In India the girls will typically be attached to boys four or five years older; in Yemen, Afghanistan, and other countries with high early marriage rates, the husbands may be young men or middle-aged widowers or abductors who rape first and claim their victims as wives afterward, as is the practice in certain regions of Ethiopia. Some of these marriages are business transactions, barely adorned with additional rationale: a debt cleared in exchange for an 8-year-old bride; a family feud resolved by the delivery of a virginal 12-year-old cousin. Those, when they happen to surface publicly, make for clear and outrage-inducing news fodder from great distances away. The 2008 drama of Nujood Ali, the 10-year-old Yemeni girl who found her way alone to an urban courthouse to request a divorce from the man in his 30s her father had forced her to marry, generated worldwide headlines and more recently a book, translated into 30 languages: *I am Nujood, Age 10 and Divorced*.

But inside a few of the communities in which parent-arranged early marriage is common practice—amid the women of Rajani's settlement, for example, listening to the mournful

Ayesha's father ordered her to put on high heels to look taller and a veil to hide her face. He warned that if he was sent to jail, he would kill her when he got out.

sound of their songs to the bathing brides—it feels infinitely more difficult to isolate the nature of the wrongs being perpetrated against these girls. Their educations will be truncated not only by marriage but also by rural school systems, which may offer a nearby school only through fifth grade; beyond that, there's the daily bus ride to town, amid crowded-in, predatory men. The middle school at the end of the bus ride may have no private indoor bathroom in which an adolescent girl can attend to her sanitary needs. And schooling costs money, which a practical family is surely guarding most carefully for sons, with their more readily measurable worth. In India, where by long-standing practice most new wives leave home to move in with their husbands' families, the Hindi term *paraya dhan* refers to daughters still living with their own parents. Its literal meaning is "someone else's wealth."

Remember this too: The very idea that young women have a right to select their own partners—that choosing whom to marry and where to live ought to be personal decisions, based on love and individual will—is still regarded in some parts of the world as misguided foolishness. Throughout much of India, for example, a majority of marriages are still arranged by parents. Strong marriage is regarded as the union of two families, not two individuals. This calls for careful negotiation by multiple elders, it is believed, not by young people following transient impulses of the heart.

So in communities of pressing poverty, where nonvirgins are considered ruined for marriage and generations of ancestors have proceeded in

exactly this fashion—where grandmothers and great-aunts are urging the marriages forward, in fact, insisting, I did it this way and so shall she—it's possible to see how the most dedicated anti-child-marriage campaigner might hesitate, trying to fathom where to begin. "One of our workers had a father turn to him, in frustration," says Sreela Das Gupta, a New Delhi health specialist who previously worked for the International Center for Research on Women (ICRW), one of several global nonprofits working actively against early marriage. "This father said, 'If I am willing to get my daughter married late, will you take responsibility for her protection?' The worker came back to us and said, 'What am I supposed to tell him if she gets raped at 14?' These are questions we don't have answers to."

I HEARD THE STORY of the rat and the elephant one day in early summer, some weeks into my time among girls who are expected to marry very young. I was in the backseat of a small car in remote western Yemen, traveling along with a man named Mohammed, who had offered to bring us to a particular village down the road.

"What happened in this village has given me strong feelings," he said. "There was a girl here. Ayesha is her name." The Prophet Muhammad's youngest wife was also named Ayesha, but this was not of interest to our Mohammed just now. He was extremely angry. "She is 10 years old," he said. "Very tiny. The man she married is 50 years old, with a big belly, like so." Spreading his arm around him, he indicated massive girth. "Like a rat getting married to an elephant."

Mohammed described the arrangement called *shighar*, in which two men provide each other with new brides by exchanging female relatives. "These men married each other's daughters," Mohammed said. "If the ages had been proper between the husbands and new wives, I don't think anyone would have reported it. But girls should not marry when they are 9 or 10. Maybe 15 or 16."

Fifty families live in the rock and concrete houses of the village we visited, between cactus stands and dry furrowed farm plots. The local leader, or sheikh, was short and red-bearded, with

a mobile phone jammed under his belt beside his traditional Yemeni dagger. He showed us to a low-ceilinged house crowded with women, babies, and girls. They sat on the carpeted floors and beds, and more kept ducking through the doorway to squeeze in; the sheikh squatted in their midst, frowning and interrupting. He regarded me dubiously. "You have children?" he asked.

Two, I said, and the sheikh looked dismayed. "Only two!" He tipped his head toward a young woman nursing a baby in one arm while fending off two small children with the other. "This young lady is 26," he said. "She has had ten."

Her name was Suad. The sheikh was her father. She had been married at 14 to a cousin he selected. "I liked him," Suad said, her voice low, as the sheikh kept his eyes upon her. "I was happy."

The sheikh made various pronouncements concerning marriage. He said no father ever forces his daughter to marry against her will. He said the medical dangers of early childbirth were greatly exaggerated. He said initiation to marriage was not necessarily easy, from the bride's point of view, but that it was pointless to become agitated about this. "Of course every girl gets scared the first night," the sheikh said. "She gets used to it. Life goes on."

His phone tootled. He extracted it from his belt and stepped outside. I pulled the scarf off my hair, something I'd seen my interpreter do when men were gone and the intimate talk of women was under way. Speaking quickly, we asked, How are you all prepared for your wedding night? Are you taught what to expect?

The women glanced toward the doorway, where the sheikh was absorbed in his phone call. They leaned forward. "The girls do not know," one said. "The men know, and they force them."

Could they tell us about young Ayesha and her elephant husband of 50? The women all started talking at once: It was an awful thing; it should have been forbidden, but they were helpless to stop it. Little Ayesha screamed when she saw the man she was to marry, said a young woman named Fatima, who turned out to be Ayesha's older sister. Someone alerted the police, but Ayesha's father ordered her to put on high heels to look

taller and a veil to hide her face. He warned that if he was sent to jail, he would kill Ayesha when he got out. The police left without troubling anyone, and at present—the women talked urgently and quietly now, because the sheikh appeared to be ending his conversation—Ayesha was living in a village two hours away, married.

"She has a mobile phone," Fatima said. "Every day, she calls me and cries."

"IF THERE WERE any danger in early marriage, Allah would have forbidden it," a Yemeni member of parliament named Mohammed Al-Hamzi told me in the capital city of Sanaa one day. "Something that Allah himself did not forbid, we cannot forbid." Al-Hamzi, a religious conservative, is vigorously opposed to the legislative efforts in Yemen to prohibit marriage for girls below a certain age (17, in a recent version), and so far those efforts have met with failure. Islam does not permit marital relations before a girl is physically ready, he said, but the Holy Koran contains no specific age restrictions and so these matters are properly the province of family and religious guidance, not national law. Besides, there is the matter of the Prophet Muhammad's beloved Ayesha—nine years old, according to the conventional account, when the marriage was consummated.

Other Yemeni Muslims invoked for me the scholarly argument that Ayesha was actually older when she had marital relations—perhaps a teenager, perhaps 20 or more. In any case her precise age is irrelevant, they would add firmly; any modern-day man demanding marriage with a young girl dishonors the faith. "In Islam, the human body is very valuable," said Najeeb Saeed Ghanem, chairman of the Yemeni Parliament's Health and Population Committee. "Like jewelry." He listed some of the medical consequences of forcing girls into sex and childbirth before they are physically mature: Ripped vaginal walls. Fistulas, the internal ruptures that can lead to lifelong incontinence. Girls in active labor to whom nurses must explain the mechanics of human reproduction. "The nurses start by asking, 'Do you know what's happening?'" a Sanaa

Long after midnight, five-year-old Rajani is roused from sleep and carried by her uncle to her wedding. Child marriage is illegal in India, so ceremonies are often held in the wee hours of morning. It becomes a secret the whole village keeps, explained one farmer.







pediatrician told me. “Do you understand that this is a baby that has been growing inside of you?”

Yemeni society has no tradition of candor about sex, even among educated mothers and daughters. The reality of these marriages—the murmured understanding that some parents truly are willing to deliver their girls to grown men—was rarely talked about openly until three years ago, when ten-year-old Nujood Ali suddenly became the most famous anti-child-marriage rebel in the world. Among Yemenis the great surprise in the Nujood story was not that Nujood’s father had forced her to marry a man three times her age; nor that the man forced himself upon her the first night, despite supposed promises to wait until she was older, so that in the morning Nujood’s new mother- and sister-in-law examined

the bloodied sheet approvingly before lifting her from bed to give her a bath. No. Nothing in those details was especially remarkable. The surprise was that Nujood fought back.

“Her case was, you know, the stone that disturbed the water,” says one of the Yemeni journalists who began writing about Nujood after she showed up alone one day in a courthouse in Sanaa. She had escaped her husband and come home. She had defied her father when he shouted at her that the family’s honor depended on her fulfilling her wifely obligations. Her own mother was too cowed to intervene. It was her father’s second wife who finally gave Nujood a blessing and taxi money and told her where to go, and when an astonished judge asked her what she was doing in the big city courthouse by herself,



Rajani and her boy groom barely look at each other as they are married in front of the sacred fire. By tradition, the young bride is expected to live at home until puberty, when a second ceremony transfers her to her husband.


In India, where new wives are expected to move in with their husband's families, *paraya dhan* refers to daughters still living with their parents. It means "someone else's wealth."

Nujood said she wanted a divorce. A prominent female Yemeni attorney took up Nujood's case. News stories began appearing in English, first in Yemen and then internationally; both the headlines and Nujood herself were irresistible, and when she was finally granted her divorce, crowds in the Sanaa courthouse burst into applause. She was invited to the United States, to be honored before more cheering audiences.

Everyone Nujood met was bowled over by her unnerving combination of gravity and poise. When I met her in a Sanaa newspaper office, she was wearing a third-grader-size black *abaya*, the full covering Yemeni women use in public after puberty. Even though she had now traveled across the Atlantic and back and been grilled by scores of inquisitive grown-ups, she was as sweet and direct as if my questions were brand-new to her. At lunch she snuggled in beside me as we sat on prayer mats and showed me how to dip my flat bread into the shared pot of stew. She said she was living at home again and attending school (her father, publicly excoriated, had grudgingly taken her back), and in her notebooks she was composing an open letter to Yemeni parents: "Don't let your children get married. You'll spoil their educations, and you'll spoil their childhoods if you let them get married so young."

Social change theory has a fancy label for individuals like Nujood Ali: "positive deviants," the single actors within a community who through some personal combination of circumstance and moxie are able to defy tradition and instead try something new, perhaps radically so. Amid the international campaigns against child marriage, positive deviants now include the occasional mother, father, grandmother, teacher, village health worker, and so on—but some of the toughest are the rebel girls themselves, each of their stories setting off new rebellions in its wake. In Yemen I met 12-year-old Reem, who obtained her divorce a few months after Nujood's; in doing so she won over a hostile judge who had insisted, memorably, that so young a bride is not yet mature enough to make a decision about divorce. In India I met the 13-year-old Sunil, who at 11 swore to her parents that she would refuse the





Although early marriage is the norm in her small Nepali village, 16-year-old Surita wails in protest as she leaves her family's home, shielded by a traditional wedding umbrella and carried in a cart to her new husband's village.



groom who was about to arrive; if they tried force, she declared, she would denounce them to police and break her father's head. "She came to us for help," an admiring neighbor told me. "She said, 'I'm going to smash his head with a stone.'"

The push to reach many more underage girls and their families, through education programs and scattered government or agency-supported efforts, is targeted way beyond just the prepubescent marriages that most easily rouse public indignation. "The public loves those kinds of stories, where there's a clear right and wrong," says Saranga Jain, an adolescent-health specialist. "But the majority of girls getting married underage are 13 to 17. We want to recharacterize the problem as not just about very young girls."

From the ICRW's point of view, *any* marriage of

a teen under 18 is a child marriage, and although definitive tallies are impossible, researchers estimate that every year 10 to 12 million girls in the developing world marry that young. Efforts to reduce this number are mindful of the varied forces pushing a teenager to marry and begin childbearing, thus killing her chances at more education and decent wages. Coercion doesn't always come in the form of domineering parents. Sometimes girls bail out on their childhoods because it's expected of them or because their communities have nothing else to offer. What seems to work best, when marriage-delaying programs do take hold, is local incentive rather than castigation: direct inducements to keep girls in school, along with schools they can realistically attend. India trains village health workers



Kandahar policewoman Malalai Kakar arrests a man who repeatedly stabbed his wife, 15, for disobeying him. “Nothing,” Kakar said, when asked what would happen to the husband. “Men are kings here.” Kakar was later killed by the Taliban.

Twelve-year-old Reem got a divorce after she won over a hostile judge who had insisted that so young a bride is not mature enough to make a decision about divorce.

called *sathins*, who monitor the well-being of area families; their duties include reminding villagers that child marriage is not only a crime but also a profound harm to their daughters. It was a Rajasthan *sathin*, backed by the *sathin*’s own enlightened in-laws, who persuaded the 11-year-old Sunil’s parents to give up the marriage plan and let her go back to school.

Because the impossible flaw in the grab-the-girl-and-run fantasy is: Then what? “If we separate a girl and isolate her from her community, what will her life be like?” asks Molly Melching, the founder of a Senegal-based organization called Tostan, which has won international respect for its promotion of community-led programs that motivate people to abandon child marriage and female genital cutting. Tostan workers encourage communities to make public declarations of the standards for their children, so that no one girl is singled out as different if not married young.

“You don’t want to encourage girls to run away,” Melching says. “The way you change social norms is not by fighting them or humiliating people and saying they’re backward. We’ve seen that an entire community can choose very quickly to change. It’s inspiring.”

THE ONE PERSON WHO EXPLAINED most eloquently to me the excruciating balance required to grow up both independent and respectful within a culture of early marriage was a 17-year-old Rajasthan girl named Shobha Choudhary. Shobha was in her school uniform, a dark pleated skirt with a tucked-in white blouse, the first time I met her. She had severe eyebrows, an erect bearing, and shiny black hair combed into a ponytail. She was in her final year of high school and a scholarly standout; in her village she had been spotted years earlier by the Veerni Project, which disperses workers throughout northern India in search of bright girls whose parents might let them leave home for a free education at its girls’ boarding school in the city of Jodhpur.

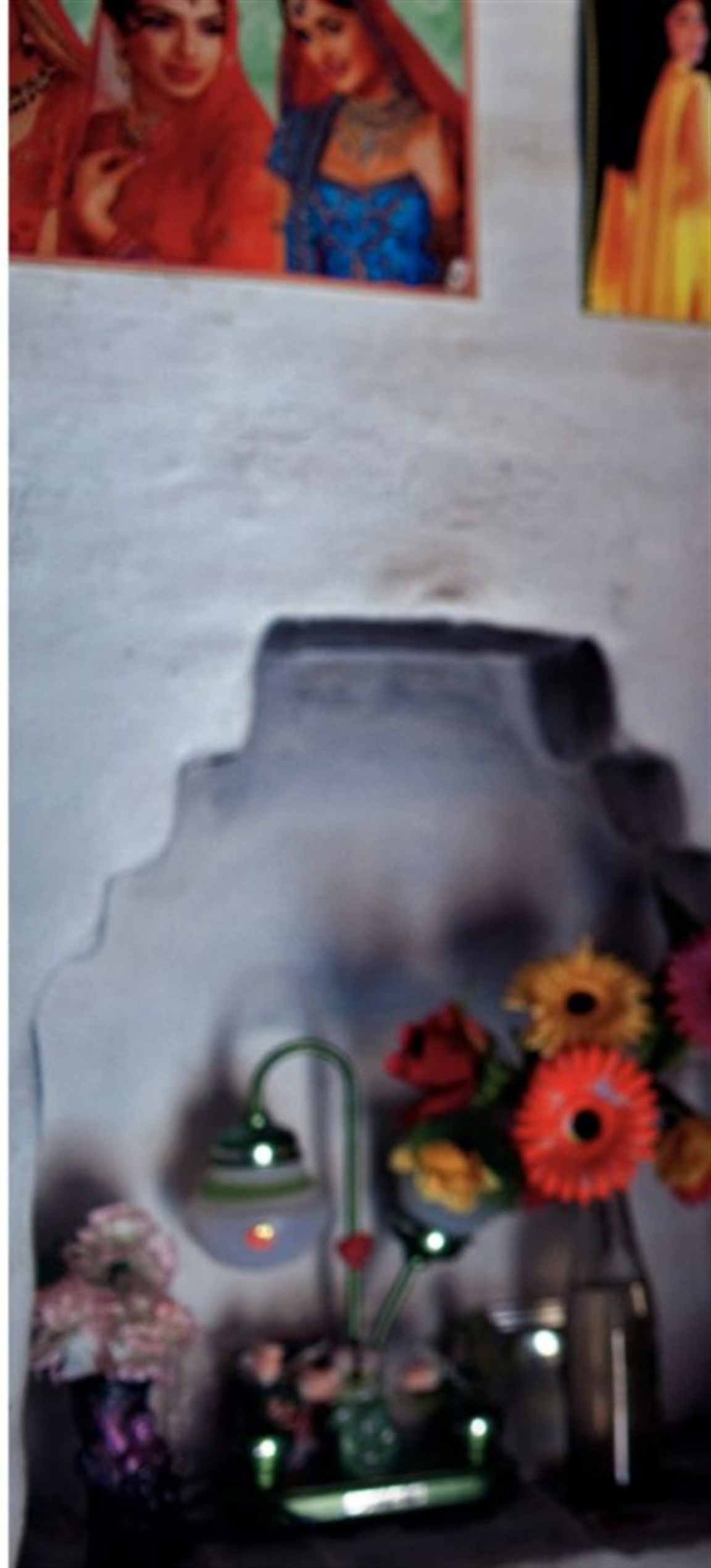
Shobha is married and has been since she was eight. Picture the occasion: a group ceremony, a dozen village girls, great excitement in a place of

great poverty. "Beautiful new clothes," Shobha told me, with a mirthless smile. "I didn't know the meaning of marriage. I was very happy."

Yes, she said, she had seen her young husband since the wedding. But only briefly. He is a few years older. So far she had managed to postpone the *gauna*, the transition to married life in his household. She looked away when I asked her impression of him and said, he is not educated. We regarded each other, and she shook her head; there was no possibility, none, that she would disgrace her parents by delaying the *gauna* forever: "I have to be with him. I'll make him study and understand things. But I will not leave him."

She wanted to go to college, she said. Her intense wish was to qualify for the Indian police force so she could specialize in enforcement of the child marriage prohibition law. She had been keeping a diary throughout high school. One of the entries read, in carefully lettered Hindi: "In front of my eyes, I'll *never ever* allow child marriages to happen. I'll save each and every girl."

Every time I visited Shobha's village, her parents served chai, or spiced tea, in their best cups, and the Shobha stories thickened in their layers of pride and dissembling and uneasiness as to what the foreign visitor was up to. It wasn't a wedding! It was only an engagement party! All right, it was a wedding, but that was before the Veerni people made their kind offer and Shobha's capability had astounded them all. It was Shobha who had figured out how to obtain electricity for the house, so that she and her younger siblings could study after dark. "I can sign things," Shobha's mother told me. "She taught me how to write my name." And now, her parents indicated, this fine episode was surely concluding—and it was time. The husband was calling Shobha's cell phone, demanding a date. Her grandmother wanted the *gauna* before old age overcame her. The classes in Jodhpur were both Shobha's passion and her delaying tactic, but Veerni support runs only through high school; to stay on and cover the cost of college, Shobha needed a donor. The email arrived after I'd returned to the United States: "How are you I miss you Mam. Mam I am pursuing B.A. 1st year I also want to do English spoken



When Sunil's parents arranged for her marriage at age 11, she threatened to report them to police in Rajasthan, India. They relented, and Sunil, now 13, stayed in school. "Studying will give her an edge against others," her mother now says.

Why must women be the ones to sacrifice, I asked, and the look Shobha gave me suggested only one of us understood the world she lives in. "Because our country is man-oriented."



course and computer course. Please reply mam fastly it is urgent for admission date in college.”

My husband and I made the donation. “Let’s see what happens,” Shobha had said to me, the last time I saw her in India. “Whatever will be, I have to adjust. Because women have to sacrifice.” We were in the cooking room of her family’s home that afternoon, and my voice rose more than I intended: Why must women be the ones to sacrifice, I asked, and the look Shobha gave me suggested that only one of us, at that moment, understood the world in which she lives. “Because our country is man-oriented,” she said.

She has completed more than a year now of post-high school study: computer training, preparation for the police exams. I receive emails from her occasionally—her English is halting but

improving—and recently my Jodhpur Hindi interpreter borrowed a video camera and sat down with her, on my behalf, in a city café. Shobha said she was studying for the next exam. She had lodgings in a safe girls’ hostel in the city. Her husband still called frequently. No gauna had yet taken place. She looked straight into the camera at one point, and in English, an enormous smile on her face, she said, “Nothing is impossible, Cynthia Mam. Everything is possible.”

Two days after I received the video, a dispatch arrived from Yemen. Newspapers were reporting that a bride from a village had been dropped off at a Sanaa hospital four days after her wedding. Sexual intercourse appeared to have ruptured the girl’s internal organs, hospital officials said. She had bled to death. She was 13 years old. □

A
cast
of thousands
clings to rocky real estate in
a narrow strip of
shore called the
intertidal
zone.

Pools

Brimming



By Mel White

Photographs
by David Liittschwager

Right: Covered and uncovered by tides each day, violet coralline algae, sea stars in orange and lavender, spiny purple sea urchins, and green sea anemones have adapted to lives of constant change.

Above: Algae share space with the creatures.







The sea star—often called a starfish, though it's no more a fish than it is a sheep-dog—ranks with the most spectacular creatures of the diverse menagerie inhabiting the shores near Bodega Bay. Big (sometimes a foot across) and obstinately colorful (some are orange, some are purple; no one knows why), the sea star is usually found in a rock fissure sprawled like a discarded toy. But despite its apparent lethargy, *Pisaster ochraceus* serves as a top predator of the intertidal zone—tiger of the tide pool—though it lacks anything like a brain.

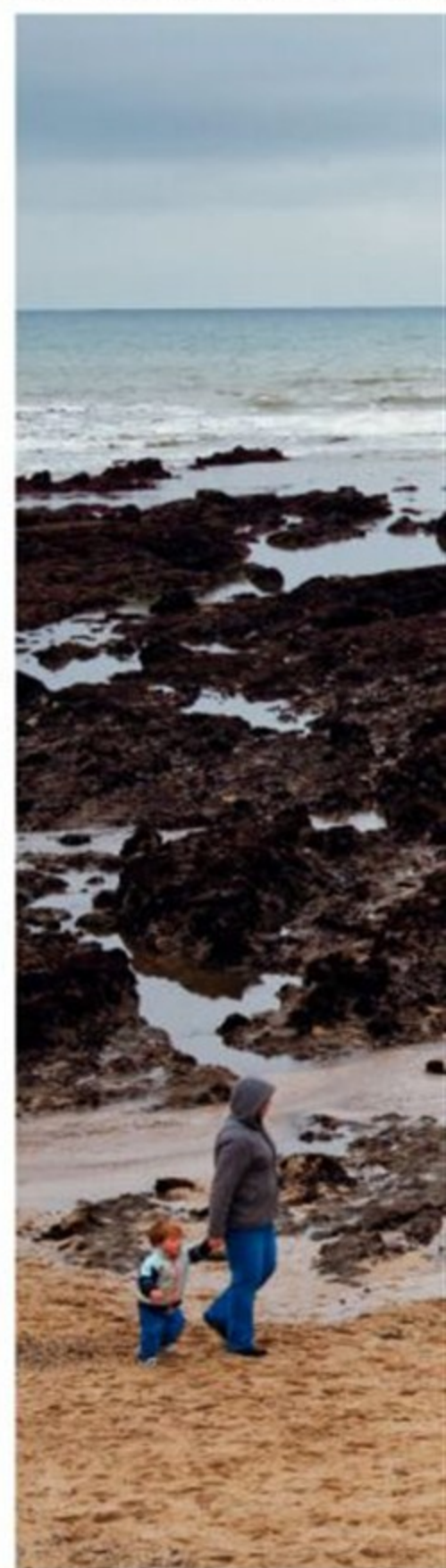
Sarah Ann Thompson, a marine biologist from the Farallon Institute in Petaluma, California, is guiding me over the rugged rocks and through the tide pools of Bodega Head's Mussel Point, 65 miles north of San Francisco. (I, in rain gear, rubber boots, and knee-pads, am trying not to slip on the shiny, slick kelp and end up as fish food.) Thompson stoops to pick up an orange star.

In a bizarre adaptation right out of a superhero movie, *Pisaster* can, in the span of a heartbeat—or what would be a heartbeat, if it had a heart—rigidify the “mutable tissue” in its normally limp body to transform itself into a structure as solid as bone. It then employs an internal hydraulic system and hundreds of suckerlike feet to grab the shells of a mussel and summon enough force to pull them apart.

“This *Pisaster* has already killed the mussel,” Thompson says, holding the sea star and the deceased in one hand and separating the mussel's



The tide's ebb and flow transforms a seascape. The Pacific Coast at Fitzgerald Marine Reserve, south of San Francisco, is covered at high tide (above, right); at low tide, rocks and pools emerge, teeming with life (see the tide pool sampler on previous pages). Some creatures are easy to spot, but it takes a sharp eye to notice some small sea spider species, less than half an inch long (above).



Preceding pages, from top **First row:** red abalone, Cockerell's doris, ringed nudibranch, variegated amphipod, grainy-hand hermit crab, ochre sea star, cabezon **Second row:** red octopus, opalescent nudibranch, mermaid's cup, smooth iridescent seaweed, San Diego lamellaria, purple sea urchin, hammerhead doris, leather star **Third row:** red rock crab, calico sculpin, colorful dendronotus, stubby frond nudibranch, rough limpet, calico sculpin **Fourth row:** red sponge nudibranch, chink snail, woody chiton, nereid worm, syllid polychaete, peanut worm, brown turban snail, red sea fern **Fifth row:** shield limpet, sea clown nudibranch, red sea fan, monkeyface pricklyback, bat star, green rope, red rock crab, flat porcelain crab **Sixth row:** splendid iridescent seaweed, Farlow's soft seaweed, blood star, six-armed star, Pacific sea comb, glycerid worm, sea palm, red gunnel, tinted wentletrap, surf grass, red sea cucumber





A photograph of a rocky coastline. Waves are crashing over rocks covered in bright green sea grass and shiny, dark kelp. The water is white with foam. An orange starfish is visible on the left side of the image, resting on the kelp. The text is in the top right corner.

Bright green sea grass and shiny kelp hold fast to rocks as waves crash over them along northern California's Bodega Head.

shells a bit with the other. “*Pisaster* has everted its stomach out through its mouth, and it’s digesting the mussel externally.”

So that creamy goo inside the mussel...?

“Yes, that’s *Pisaster*’s stomach. When it’s finished eating, it pulls its stomach back inside itself and goes on its way.”

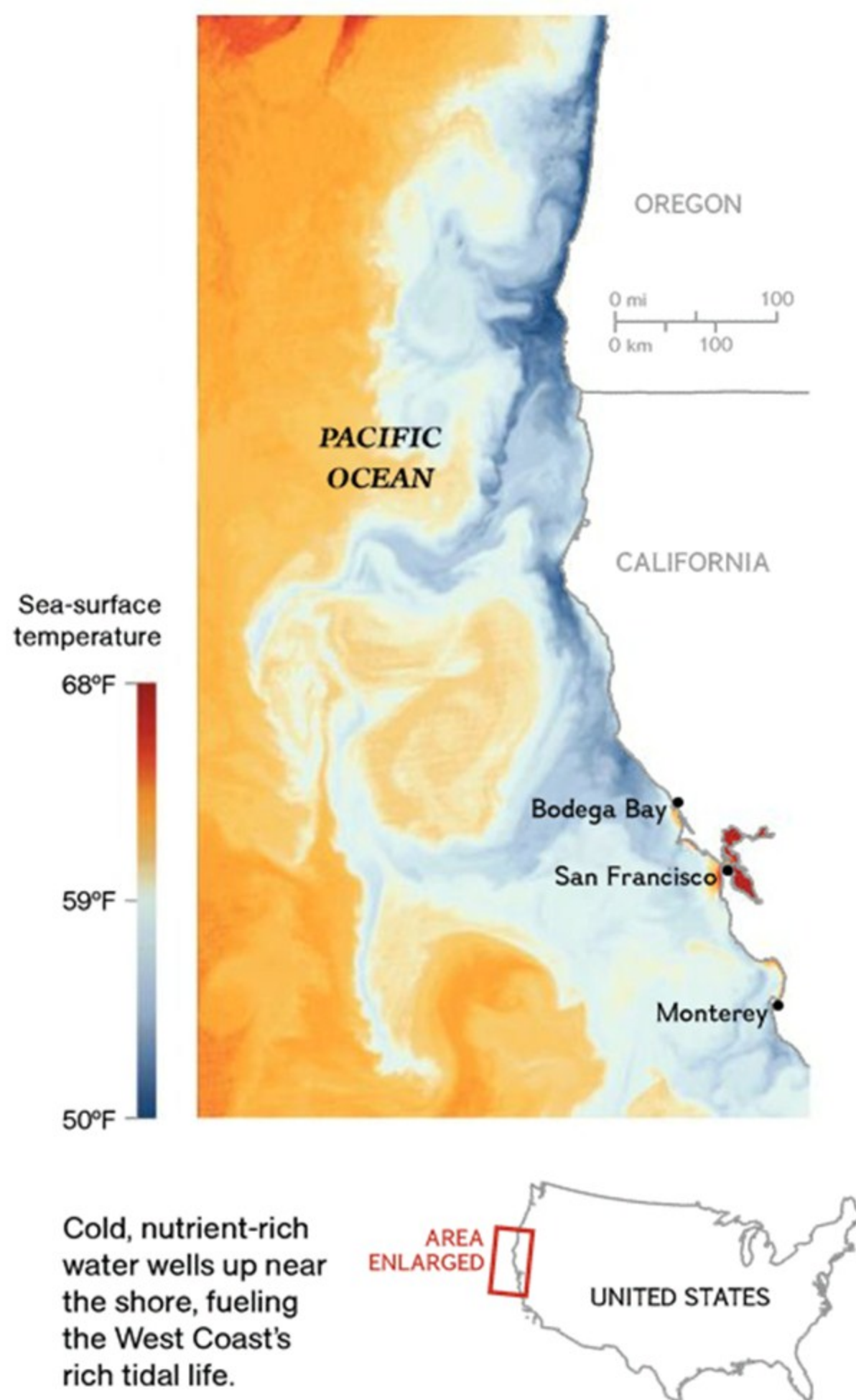
Tide pools form in zones of rocky shoreline where ocean and land meet—strips of shore, sometimes only a few yards wide, where everything is covered and uncovered by tides each day. John Steinbeck famously described this zone as “ferocious with life.” The observation applies spatially—lots of things are happening in a relatively small area—but also temporally: Things happen fast between tides.

Biologists value the intertidal zone as an easily observable model of ecological processes that happen on much larger scales. Those who study life zones—the way flora and fauna change from the desert up to alpine peaks—must traverse many miles of landscape to experience a wide range of habitats. The intertidal strip displays zonation—from the sea grass at the bottom up through strata of sea anemones and mussels and barnacles to the limpets at the top—all within a few steps.

When a tornado rips through a mature forest, and growth begins anew, centuries will pass as grasses give way to shrubs and pioneer trees eventually yield to the species of an old-growth forest. When a wave-tossed log scrapes away a patch of intertidal life down to the bare rock, biologists can watch mature life return practically before their eyes, the cycle of succession lasting just a few years.

A coincidence of geology and climate makes the northwestern coast of North America one of the world’s most diverse and productive intertidal regions. Near-shore upwelling of cold Pacific Ocean currents provides nutrient-rich water, winter freezes and rock-scraping ice are

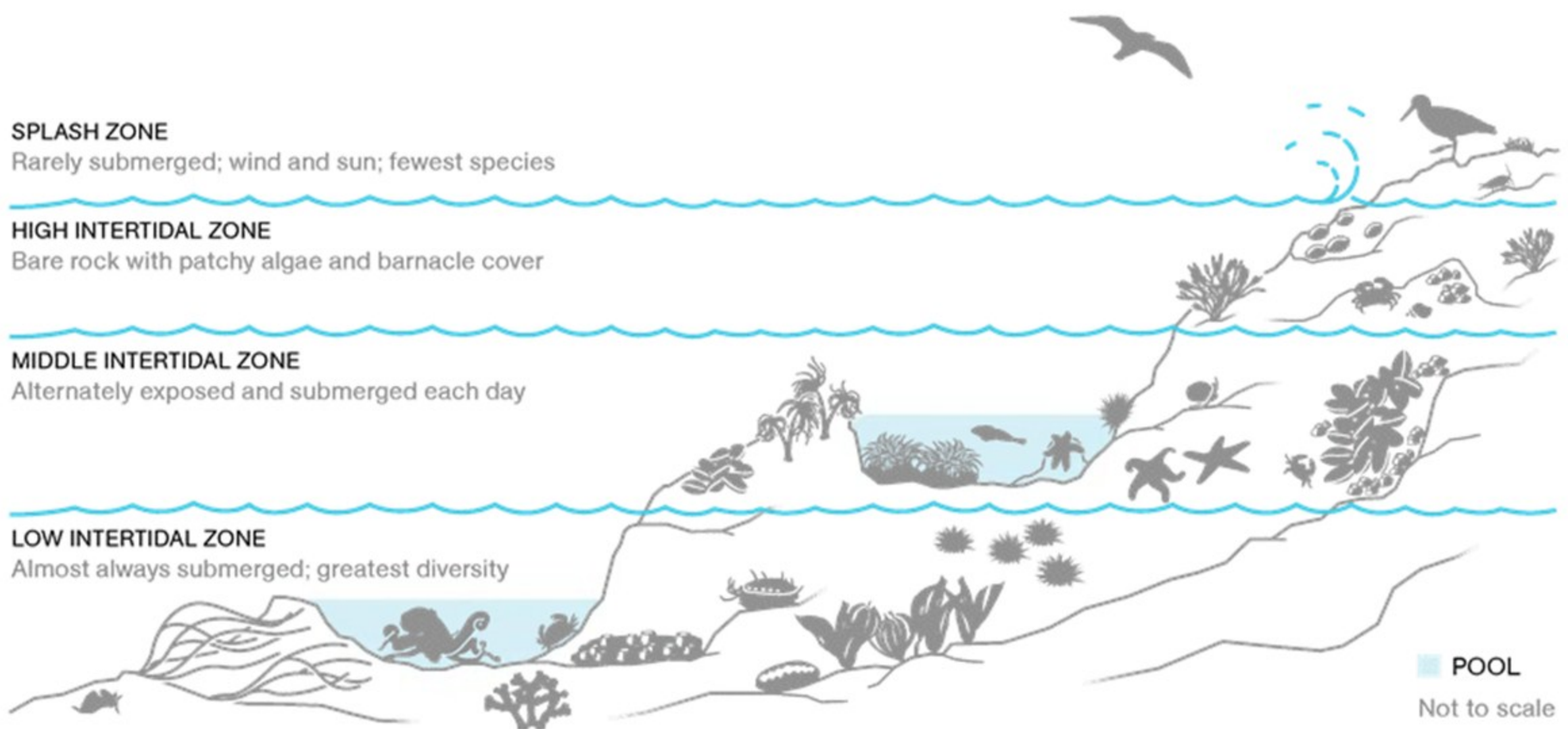
Writer Mel White covered New Guinea’s Foja Mountains for the June 2010 issue. David Liittschwager’s photographs appeared in February 2010 in “Within One Cubic Foot.”



rare, and abundant fog softens the drying effect of sunlight on marine animals that must spend half their lives or more out of the sea.

The rocks and pools here create an abundance of opportunities and host a diversity of life to rival any rain forest. *Pisaster* is just one of scores of species that have adapted to innumerable microhabitats with a seemingly endless variety of physical shapes and lifestyles. One little worm can shoot a harpoon out of its head to stab its prey. A limpet tends and guards its own farm plot. A seaweed releases acid for defense when it’s injured. A nudibranch (which looks like a gussied-up slug) eats poisonous creatures and implants stinging cells under its own skin to repel predators.

Why all the aggression? It’s simply the result



LAYERS OF LIFE The habitats of the intertidal zone vary dramatically. On higher ground, organisms are submerged only briefly each day, facing long exposure to the drying effects of sun and wind. The low-tide zone is almost always underwater. Tide pools provide refuge for animals that prefer to be submerged continuously.

of lots of plants and animals competing for resources in a highly productive but limited space. In nature, as in real estate, location is everything, and the intertidal zone is Park Avenue.

ERIC SANFORD LIKES TO PERFORM a kind of magic trick for his students at Bodega Marine Laboratory, giving his introductory patter in the classroom and heading down to the rocky coast for the payoff.

First, the audience must understand the concept of phylum (plural, phyla): the organizing principle for classifying the entire animal kingdom. The German word for phylum, *bauplan* (body plan), is helpful here in that all animals are grouped according to their physical structure. For instance, everything with a notochord (which would be a spine for sharks, pythons, pelicans, you) belongs in the phylum Chordata. Butterflies and shrimps and other animals with jointed legs belong to Arthropoda. Depending on who's doing the classifying, biologists list around 33 phyla.

Next, Sanford leads his audience—in this case, me—on the short walk to Horseshoe Cove, another indentation in the rugged shoreline of

Bodega Head. After a little exploration through the thick growth of kelp and sea grass, he picks up a promising-looking rock about the size and shape of a slightly melted bowling ball.

“Let’s see what we can find,” he says. “This yellow crust is a sponge, in the phylum Porifera. This sea anemone is in Cnidaria, and this tiny sea star is in Echinodermata. This snail and this nudibranch are both in Mollusca, and here are several tube worms, in Annelida.

“We’ve got a couple of things here that look something like sponges, but they’re in Bryozoa. Here’s a tunicate, also called a sea squirt, which is in Chordata, and a crab, in Arthropoda.” It takes some searching, but he comes up with one more: “And this is a flatworm, in Platyhelminthes.”


So there’s the magic. Eric Sanford is holding, in one hand, representatives of more than one-fourth of all the animal life on Earth: nine phyla on one rock. In comparison, the entire land surface of the planet, from Poles to Equator, is home to only about a dozen phyla.

Sanford is actually a little crestfallen because he can’t find a peanut worm, an odd thing in the phylum Sipuncula that would give us an even ten. The thrill would have been strictly numerical,





These residents (left) of California's intertidal zone range in size from one-quarter inch to one and a half inches. Clockwise from top right: a shrimp; a sea anemone with two young; a feather duster worm (its bundle of tentacles breathes and catches food); a crustacean with seven pairs of legs; a sea star displaying tube feet, used for locomotion; a type of mollusk called a lined chiton; a nudibranch, or sea slug; and a cluster of fish eggs. Another crustacean (right) has evolved a shape and color to blend in with the blades of sea grass where it lives.



Gooseneck barnacles (top) occupy rock faces in the middle intertidal zone, while sea anemones (bottom) thrive on the low shore. Predatory sea stars move actively in between.

JIM ZIPP, PHOTO RESEARCHERS INC.



though. I've already seen a peanut worm, and it has all the aesthetic appeal of used chewing gum. (I must admit, however, that the one thing it does, it does very well: extending a hydraulically powered, tentacle-tipped proboscis several times the length of its body to grab tiny bits of drifting dead stuff. Sanford calls it "this crazy sort of Dr. Seuss-like thing.")

"A lot of this diversity occurs because life first evolved in the sea," Sanford says. "And intertidal systems are really a microcosm of the ocean in general. In a tide pool, for the few hours that the tide is out, you're able to access it all."

A COUPLE OF DAYS LATER, I'm rock-hopping above Horseshoe Cove with Jackie Sones, research coordinator at the Bodega Marine Reserve. "This," she says, holding up a pale orange creature about the size of her fingernail, "is a pycnogonid, commonly called a sea spider."

Through a hand lens, it does in fact resemble a spider, although one with a touch of the Michelin Man, body and legs ribbed and puffy. I can see this thing, blown up a couple of thousand times, doing battle with some outer space monster in a low-budget fifties sci-fi flick.

"It uses its proboscis to puncture sea anemones and suck out fluids," Sones says. But this minute predator has a nurturing side. Sones upends the pycnogonid to reveal a cluster of tiny spheres like whitish caviar. "The males care for the developing young," she says. "They gather the eggs from different females and hold them with specially modified legs." Pycnogonids fascinate biologists because they're one of very few types of animals in which only males care for the young.

Juvenile development of intertidal creatures varies nearly as much as their physical forms. Many go through a free-swimming larval stage lasting weeks or months, venturing into the immense ocean before settling down as adults on a patch of rock.

We kneel to examine one of those larval roamers—or rather the resulting adult. The giant green sea anemone, *Anthopleura xanthogrammica*, is a formidable predator, though it

waits for unsuspecting prey to wander within reach rather than actively hunting. Resembling a fist-size blob of lime Jell-O out of the water, *Anthopleura* blooms when submerged, extending delicate tentacles around a sucking maw that swallows prey whole. Sea anemones show their kinship to jellyfish in their use of stinging structures called nematocysts, which they fire like microscopic darts to stun prey. I extend a finger as an anemone taste test and feel only a faint sticky sensation. If I were a crab, I'd be lunch.

Once they've set up housekeeping, *Anthopleura* and many of its neighbors in the intertidal zone show exceptional longevity, both individually and as species. Sea anemones have lived decades in laboratories without showing any discernible signs of aging, and some in the wild are believed to be 150 years old or more. "Short of predation or other fatal accidents," one reference book states, "anemones are potentially immortal."

Biologists question, though, how even highly adaptable intertidal plants and animals will respond to threats they've never known before. Local issues range from pollution and siltation due to coastal runoff to an increase in the harvest of some seaweeds, fueled by the demand for natural food.

Of far greater significance is ocean acidification caused by higher levels of atmospheric carbon dioxide. Mollusks, crustaceans, and even coralline algae are among the living things that use calcium in their structures, a process that could be impeded by higher acidity levels in seawater. Rising ocean temperatures are also a threat: Warm water holds less oxygen than cold water. National and state marine reserves can help protect against overharvest of ocean resources, but they're just as vulnerable as the rest of the seas in the face of global climate change.

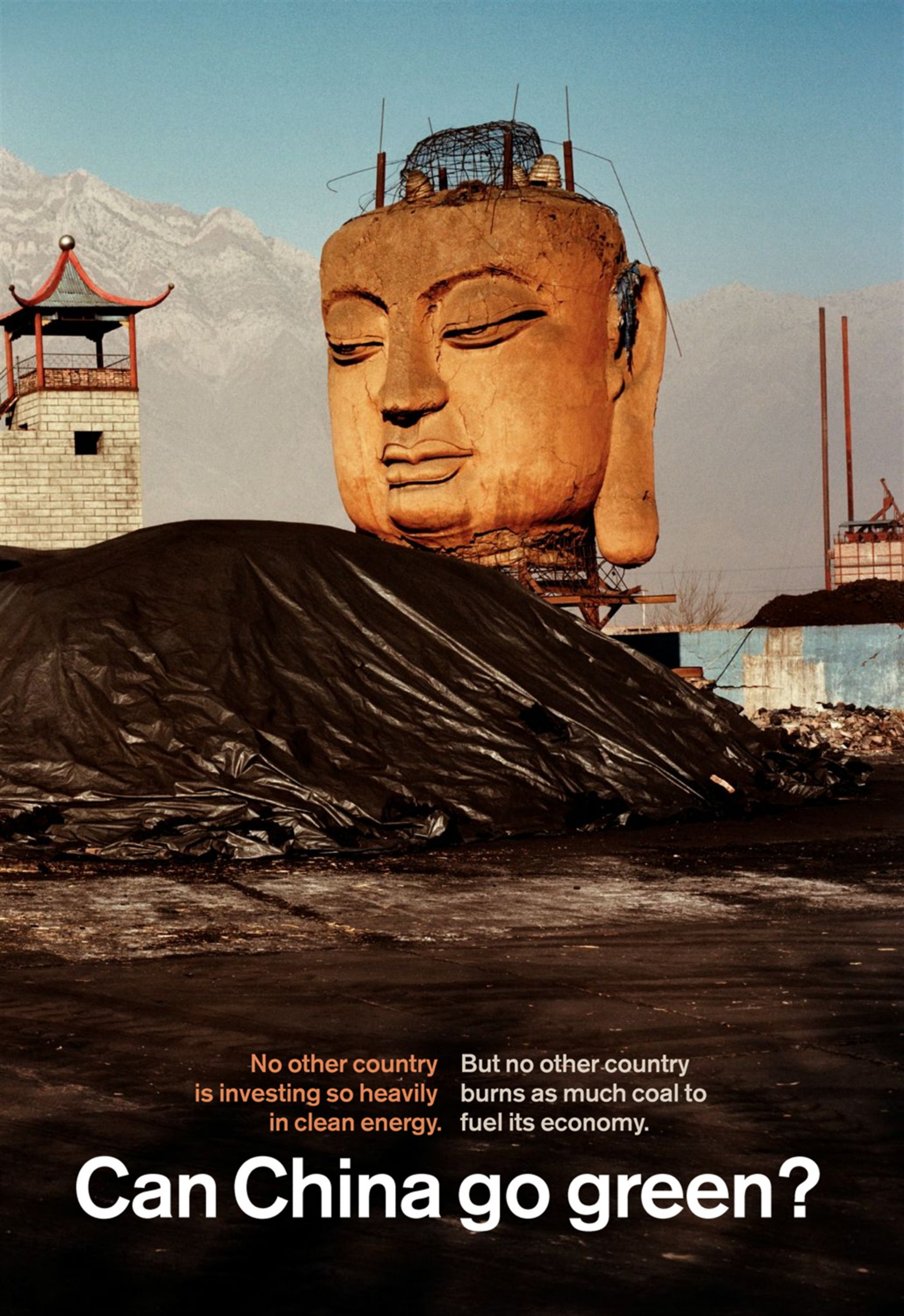
In a meditation on the interconnectedness of life, Steinbeck wrote, "It is advisable to look from the tide pool to the stars and then back to the tide pool again." As a microcosm of the ocean—the nursery of all life including our own—the intertidal zone serves as another galaxy in the universe, one easily within our grasp. □



A decorator crab disguises itself by hooking on bits of algae. The penpoint gunnel comes in colors from reddish to green to brown, depending on its surroundings. If the camouflage works, intertidal zone predators won't notice these potential meals.



A coal yard in northern China comes with a Buddha. Coal reserves could run low in a few decades, making green energy in China a must.



No other country
is investing so heavily
in clean energy.

But no other country
burns as much coal to
fuel its economy.

Can China go green?

Rizhao, in Shandong Province, is one of the hundreds of Chinese cities gearing up to really grow. The road into town is eight lanes wide, even though at the moment there's not much traffic. But the port, where great loads of iron ore arrive, is bustling, and Beijing has designated the shipping terminal as the "Eastern bridgehead of the new Euro-Asia continental bridge."

A big sign exhorts the residents to "build a civilized city and be a civilized citizen."

In other words, Rizhao is the kind of place that has scientists around the world deeply worried—China's rapid expansion and new-found wealth are pushing carbon emissions ever higher. It's the kind of growth that helped China surge past the United States in the past decade to become the world's largest source of global warming gases.

And yet, after lunch at the Guangdian Hotel, the city's chief engineer, Yu Haibo, led me to the roof of the restaurant for another view. First we clambered over the hotel's solar-thermal system, an array of vacuum tubes that takes the sun's energy and turns it into all the hot water the kitchen and 102 rooms can possibly use. Then, from the edge of the roof, we took in a view of the spreading skyline. On top of every single building for blocks around a similar solar array sprouted. Solar is in at least 95 percent of all the buildings, Yu said proudly. "Some people say 99 percent, but I'm shy to say that."

Whatever the percentage, it's impressive—outside Honolulu, no city in the U.S. breaks single digits or even comes close. And Rizhao's solar water heaters are not an aberration. China now leads

the planet in the installation of renewable energy technology—its turbines catch the most wind, and its factories produce the most solar cells.

We once thought of China as the "yellow peril" and then the "red menace." Now the colors are black and green. An epic race is on, and if you knew how the race would come out—if you knew whether or how fast China could wean itself off coal and tap the sun and wind—then you'd have the single most important data point of our century. The outcome of that race will determine how bad global warming is going to get. And right now the answer is still up in the air.

LITERALLY up in the air. Visitors to China are instantly struck, of course, by the pollution shrouding every major city. Slowly those skies are clearing a little, at least in places like Beijing and Shanghai, as heavy industry is modernized or moved out of town. And the government has shut down many of the smallest and filthiest coal-fired power plants. Indeed, the country now leads the world in building what engineers call supercritical power stations, which produce far less smog than many of the hulking units



China's hurry-up approach to weaning itself from fossil fuels finds a sleek symbol in a bullet train at Shanghai's Hongqiao Railway Station, its 220-mile-an-hour speeds awing travelers. Within a few years the country will have as much high-speed track—some 8,000 miles—as the rest of the world combined.

still online in the U.S. Presumably China will get steadily cleaner as it gets richer—that's been the story elsewhere.

But—and it's a crucial but—you can clean the air without really cleaning the air. The most efficient coal-fired power plants may not pour as much particulate matter, sulfur dioxide, and nitrogen oxides into the atmosphere, but they still produce enormous quantities of carbon dioxide. Invisible, odorless, generally harmless to humans—and the very thing that's warming the planet. The richer China gets, the more it produces, because most of the things that go with wealth come with a gas tank or a plug. Any Chinese city is ringed with appliance stores; where once they offered electric fans, they now carry vibrating massage chairs.

"People are moving into newly renovated

apartments, so they want a pretty, new fridge," a clerk told me. "People had a two-door one, and now they want a three-door." The average Shanghainese household already has 1.9 air conditioners, not to mention 1.2 computers. Beijing registers 20,000 new cars a month. As Gong Huiming, a transportation program officer at the nonprofit Energy Foundation in Beijing, put it: "Everyone wants to get the freedom and the faster speed and the comfort of a car."

That Chinese consumer revolution has barely begun. As of 2007, China had 22 cars for every 1,000 people, compared with 451 in the U.S.

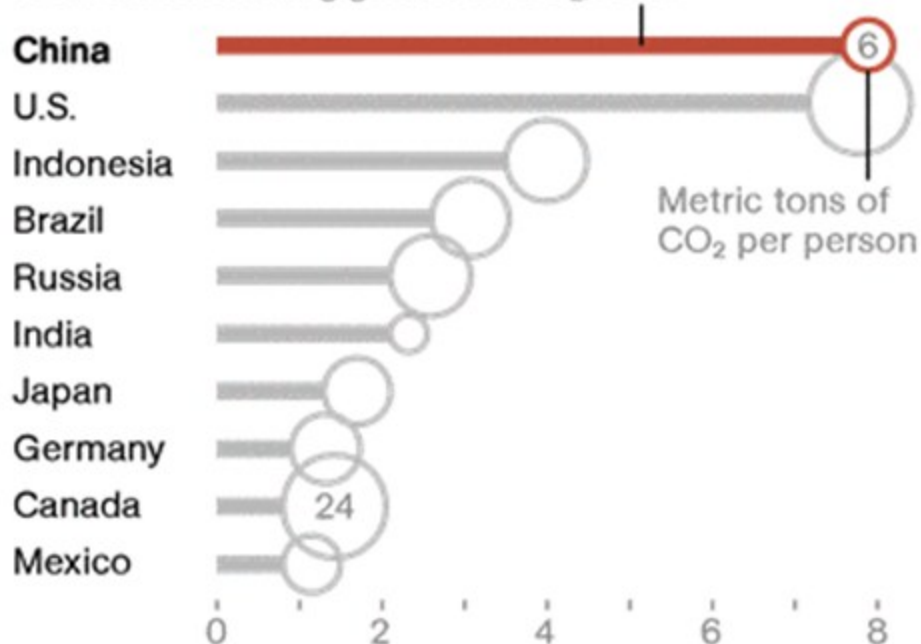
Environmental journalist Bill McKibben is a scholar-in-residence at Middlebury College. Based in Shanghai, photographer Greg Girard has been documenting China since 1983.

Change (and CO₂) in the Air

Burning more than three billion tons of coal a year—more than the U.S., Europe, and India combined—China tops the world in emissions of CO₂ and other atmosphere-warming gases. To slow emissions without impeding its supercharged economic growth, the nation has also become a leader in clean energy, generating nearly 20 percent of its electricity from renewable sources, mostly hydro and wind.

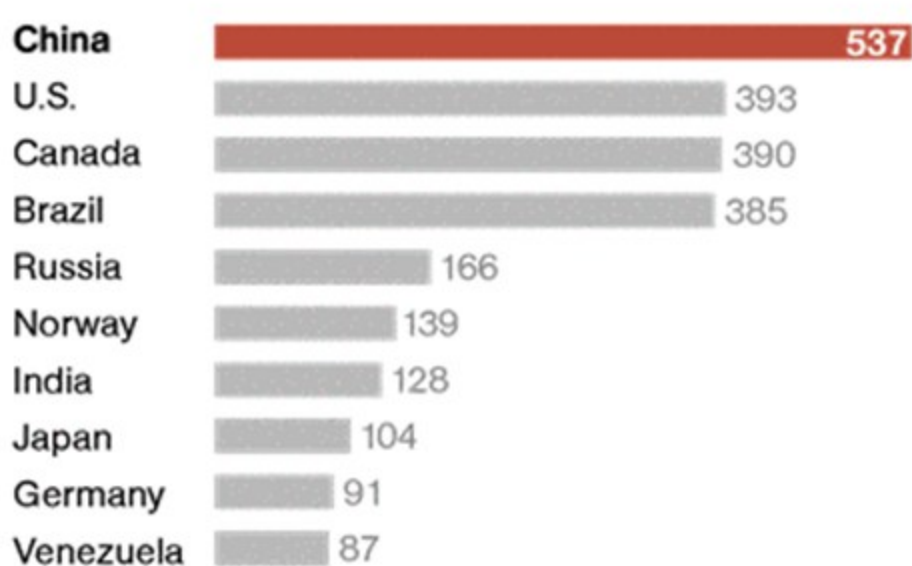
Greenhouse gas emissions

Total emissions in gigatons of CO₂, 2007



Electricity production from renewable sources

Billion kilowatt hours a year, 2008



LAWSON PARKER AND
KAITLIN M. YARNALL, NGM STAFF
SOURCES: MCKINSEY & COMPANY;
POPULATION REFERENCE BUREAU; U.S. ENERGY
INFORMATION ADMINISTRATION

Once you leave the major cities, highways are often deserted and side roads are still filled with animals pulling carts. “Mostly, China’s concentrated on industrial development so far,” said Deborah Seligsohn, who works in Beijing for the Washington, D.C.-based World Resources Institute. Those steel mills and cement plants have produced great clouds of carbon, and the government is working to make them more efficient. As the country’s industrial base matures, their growth will slow. Consumers, on the other hand, show every sign of speeding up, and certainly no Westerner is in a position to scold.

Bill Valentino, a sustainability executive with the pharmaceutical giant Bayer who has long been based in Beijing, recently taught a high school class at one of the international schools. He had his students calculate their average carbon footprint, and they found that if everyone on the planet lived as they did, it would take two to four Earths’ worth of raw materials to meet their needs. So they were already living unsustainable lives. Valentino—an expat American who flies often—then did the same exercise and found that if the whole world adopted his lifestyle, we’d require more than five planet Earths.

China has made a low-carbon economy a priority, but no one is under any illusion about the country’s chief aim. By most estimates, China’s economy needs to grow at least 8 percent a year to ensure social stability and continued communist rule. If growth flags, Chinese may well turn rebellious; there are estimates of as many as 100,000 demonstrations and strikes already each year. Many of them are to protest land takeovers, bad working conditions, and low wages, so the government’s main hope is to keep producing enough good jobs to absorb a population still

An instant suburb of high-rises shoots up on the outskirts of the wealthy coal-mining city of Ordos in Inner Mongolia. The feverish growth of urban areas, with their energy-hungry buildings and appliances, has contributed to a tripling of China’s power demand since 2000. In Zhenbeipu consumers grab coupons for free cell phones.





What doesn't go up in smoke ends up in a landfill as a truck dumps a load of ash from a coal-fired power plant visible on the horizon in Shizuishan. A 2010 Greenpeace report cites toxic coal ash as China's largest source of solid industrial waste, dispersed by wind and rain into the environment.



Under a bright sky near Shizuishan, a technician makes the rounds of China's first large-scale solar farm. Connected to the grid in 2009, the plant provides ten megawatts of electricity, enough for 10,000 homes. Two-thirds of China's vast land is ideal for solar power.

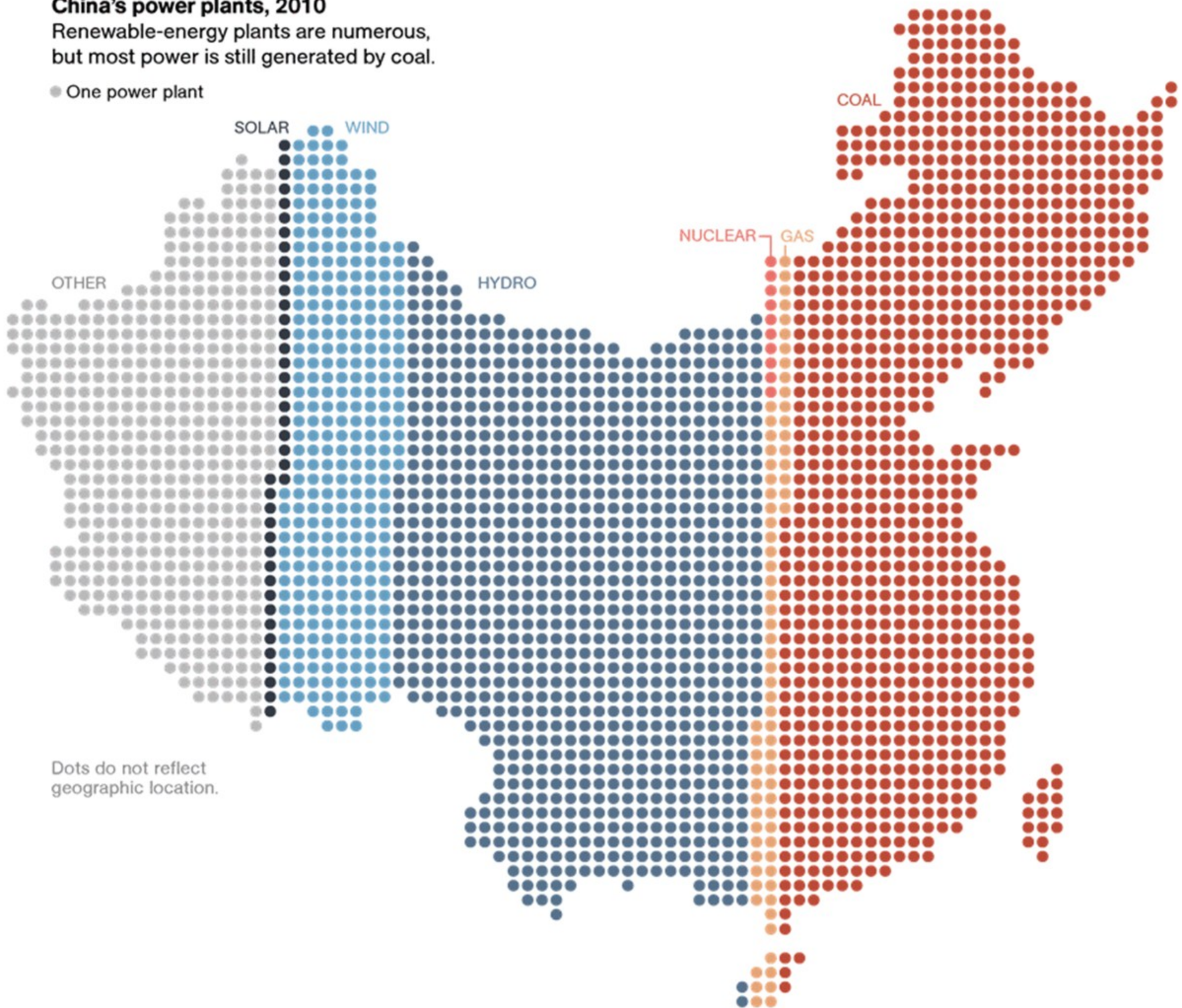




China's power plants, 2010

Renewable-energy plants are numerous, but most power is still generated by coal.

● One power plant



China's power generation, terawatt-hours



A Coal-fueled Country

Despite aggressive growth in alternative energy, China will have to burn even more coal to power its booming economy. A forecast for 2030 (above) indicates that if China meets current policy commitments, coal will continue to supply 70 percent of its energy, double the amount used now. To emit no more greenhouse gases in 2030 than today, China would have to rely on green energy for two-thirds of its power generation.

NOTE: ONE TERAWATT-HOUR = 1 BILLION KILOWATT-HOURS. ONE KILOWATT-HOUR WILL POWER A 100-WATT LIGHTBULB FOR TEN HOURS.

LAWSON PARKER AND KAITLIN M. YARNALL, NGM STAFF

SOURCES: PLATTS/UDI WORLD ELECTRIC POWER PLANTS DATABASE; MCKINSEY & COMPANY

We took in a view of the skyline. On top of every building for blocks around a solar array sprouted.

pouring out of the poor provinces with high hopes for urban prosperity.

Increasingly, though, Chinese anger is directed at the environmental degradation that has come with that growth. On one trip I drove through a village north of Beijing where signs strung across the road decried a new gold mine for destroying streams. A few miles later I came to the mine itself, where earlier that day peasants had torn up the parking lot, broken the windows, and scrawled graffiti across the walls. A Chinese government-sponsored report estimates that environmental abuse reduced the country's GDP growth by nearly a quarter in 2008. The official figures may say the economy is growing roughly 10 percent each year, but dealing with the bad air and water and lost farmland that come with that growth pares the figure to 7.5 percent. In 2005 Pan Yue, vice minister of environmental protection, said the country's economic "miracle will end soon, because the environment can no longer keep pace." But his efforts to incorporate a "green GDP" number into official statistics ran into opposition from Beijing.

"BASICALLY," said one Beijing-based official who refused to be identified (itself a reminder of how sensitive these topics are), "China seeks every drop of fuel—every kilowatt and every kilojoule it can get a hold of—for growth." So the question becomes, What will that growth look like?

One thing it already looks like is: big and empty. Ordos, in Inner Mongolia, may be the fastest growing city in China; even by Chinese standards it has an endless number of construction cranes building an endless number of apartment blocks. The city's great central plaza looks as large as Tiananmen Square in Beijing, and towering statues of local-boy-made-good Genghis Khan rise from the concrete plain, dwarfing the few scattered tourists who have made the trek here. There's a huge new theater, a modernist museum, and a remarkable library built to look like leaning books. Coal built this Dubai-on-the-steppe. The area boasts one-sixth of the nation's total reserves, and as a result, the city's per capita income had risen to \$20,000 by 2009.

(The local government has set a goal of \$25,000 by 2012.) It's the kind of place that needs some environmentalists.

And indeed it has at least one. In the neighboring city of Baotou, a steelmaking center whose mines also supply half the planet's rare earth minerals (see page 136), I found Ding Yaoxian ensconced in the headquarters of the nonprofit Baotou City Environment Federation, on the second floor of a day center for retired party cadres, who were playing badminton on the mezzanine. Director Ding is one of the most cheerful and engaging Chinese I've ever met; he's needed every bit of charisma to build his association into a real force, numbering by his account a million area citizens. Issued little green identity cards, they serve as a kind of volunteer police force. "If people from the association see someone spilling trash, they go and sit on their doorstep," Ding said. "The government can't have eyes everywhere. A voluntary organization can put more pressure on. It can shame."

But the campaigns the group focuses on most of the time make clear how nascent environmental concern in China still is. They've handed out a million reusable shopping bags—but also hundreds of thousands of small folding paper cups, so that people will stop spitting on the street. One minor victory: When showing those hundreds of thousands of new condo units, real estate agents used to hand customers plastic booties to go over their dirty shoes; now they supply washable cloth socks. The association has tried to introduce the concept of garage sales, in a country where secondhand goods carry a stigma. And members have launched a big effort to teach Inner Mongolians to smile. "In the West people are happy and smiling, and that makes people feel positive," Ding said. His deputy, Feng Jingdong, added, "We tell them, Use your personality to get people to enjoy themselves instead of using resources." The three of us were eating a delicious lunch at a nearby restaurant (lamb is the staple here), and when we were finished, Ding made sure to ask for a doggie bag. "That's one of our campaigns," he said. "Before, it felt like you lost face if you did that."

China's green effort is being overwhelmed by the sheer scale of the coal-fueled growth. It's a dark picture.

There was one truly significant sign of greening long under way in the region: a massive tree-planting campaign designed to hold the fragile soil in place. Flatbed trucks packed with seedlings were the second most common sight along area roads (outnumbered ten to one, it seemed, by trucks carrying coal from the mines). Ding estimated that he'd planted 100,000 trees with his own hands. "It used to be very dusty here, with lots of sandstorms," he said. "But we had 312 blue sky days last year, and every year there are more."

IN SEARCH OF further reassurance that China's booming growth held real seeds of environmental possibility, I drove 170 miles south of Beijing to the (redundancy alert) booming city of Dezhou. Approaching along National Highway 104, I got a sudden glimpse of one of the world's most remarkable buildings, the Sun-Moon Mansion. It looks like a convention center surrounded by the rings of Saturn, great tracks of solar panels providing all its hot water and electricity. Behind the hotel, a sister building serves as the headquarters of Himin Solar Corporation, which claims to have installed more renewable energy than any other company on Earth. (Chinese enterprises are sometimes the beneficiaries of largesse from Beijing, such as low-interest loans that may never need to be repaid in full.)

Himin's main products are those humble solar-thermal tubes that covered the rooftops in Rizhao. And as it turns out, they cover a lot of other real estate. Huang Ming, who founded the company, estimates that it's erected more than 160 million square feet of solar water heaters. "That means 60 million families, maybe 250 million people altogether—almost the population of the United States," he said. Huang, an ebullient fellow in faded black Dockers who used to be a petroleum engineer, sells some of the best solar-thermal systems in China, but even he admits that it's fairly simple technology. He says that the key to his company's success has been opening people's minds, which it's done with revival-style marketing campaigns that storm one city at a time. "We do road showing, lecturing, PowerPointing," he said. And now

they're harnessing the power of sightseeing too: The Sun-Moon Mansion is merely the anchor of a vast solar city that will soon include a solar "4-D" cinema, a solar video-game hall, a huge solar-powered Ferris wheel, and solar-powered boats to rent from a solar marina.

The company showroom, Feel It Hall, captures a few contradictions. The solar panels heat water for hot tubs and have giant flat-screen TVs above each. But that's the only way to sell the idea of renewable energy, Huang insisted, as he described the gigantic apartment towers he's building on the edge of town, with racks of solar panels that curve like the back of a dragon. "At night that's what you see—a floating dragon," he said. "So many developers come to our Solar Valley to copy from us, to learn from us. That's just what I wanted."

He's especially happy that some of those visitors come from abroad. Dezhou hosted the International Solar Cities World Congress in 2010, and he's set up an international-experts mansion for visiting dignitaries. "If all the people of the U.S.A. enjoyed solar hot water, Obama would win five Nobel Prizes!" he said. But it's going to take a while for America to catch up. Most of the U.S.'s minuscule capacity is used to heat swimming pools. Jimmy Carter had solar water heaters installed on the roof of the White House in 1979, but they came down in the Ronald Reagan years; new ones are due to go up this year.

It's not the only instance of the Chinese taking an American lead and running with it. Suntech has emerged as one of the top two leading makers of solar photovoltaic panels in the world. New employees are added weekly, and on their first day on the job they watch Al Gore in *An Inconvenient Truth*. The young tour guide showing me around the company's headquarters in Wuxi,

A perfect site for wind and solar farms, the smoky factories around Shizuishan rely on coal-fired power plants (top), a legacy of Mao Zedong's directive in the 1950s to move industry inland against the threat of foreign attack. Day laborers (bottom) easily find work sorting coal from area mines.



Inside Beijing's first American-style mall, one of the largest anywhere, more than 500 shops vie for customers. Unleashed demand for must-have items like cars and air conditioners is turning China into the world's biggest energy consumer.





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Scenery for the industrial age, the cooling towers at the Xinglongzhuang power station mark one of China's first efforts to generate electricity from recycled coal-mining waste. Building an average of one coal-fired plant a week, China is outfitting many with the latest pollution-cutting technology.



China's growth opens real opportunities for environmental progress—not just solar panels and wind turbines.

near Shanghai, paused by the photos of solar panels at base camp on Mount Everest and the portrait of her boss, Shi Zhengrong, named by *Time* as one of its “heroes of the environment.” “It’s not only a job,” she said, a tear welling in her eye. “I have...mission!”

Of course, that tear might have come in part from the air. Wuxi was among the dirtiest cities I’d ever visited: The 100-degree-Fahrenheit air was almost impossible to breathe. The solar array that forms the front of the Suntech headquarters slanted up to catch the sun’s rays. Because of the foul air, it operated at only about 50 percent of its potential output.

IN THE END, anecdote can take you only so far. Even data are often suspect in China, where local officials have a strong incentive to send rosy pictures off to Beijing. But here’s what we know: China is growing at a rate no big country has ever grown at before, and that growth is opening real opportunities for environmental progress. Because it’s putting up so many new buildings and power plants, the country can incorporate the latest technology more easily than countries with more mature economies. It’s not just solar panels and wind turbines. For instance, some 25 cities are now putting in or expanding subway lines, and high-speed rail tracks are spreading in every direction. All that growth takes lots of steel and cement and hence pours carbon into the air—but in time it should drive down emissions.

That green effort, though, is being overwhelmed by the sheer scale of the coal-fueled growth. So for the time being, China’s carbon emissions will continue to soar. I talked with dozens of energy experts, and not one of them predicted emissions would peak before 2030. Is there anything that could move that 2030 date significantly forward? I asked one expert in charge of a clean-energy program. “Everyone’s looking, and no one is seeing anything,” he said.

Even reaching a 2030 peak may depend in part on the rapid adoption of technology for taking carbon dioxide out of the exhaust from coal-fired power plants and parking it underground

in played-out mines and wells. No one knows yet if this can be done on the scale required. When I asked one scientist charged with developing such technology to guess, he said that by 2030 China might be sequestering 2 percent of the carbon dioxide its power plants produce.

Which means, given what scientists now predict about the timing of climate change, the greening of China will probably come too late to prevent more dramatic warming, and with it the melting of Himalayan glaciers, the rise of the seas, and the other horrors Chinese climatologists have long feared.

It’s a dark picture. Altering it in any real way will require change beyond China—most important, some kind of international agreement that transforms the economics of carbon. At the moment China is taking green strides that make sense for its economy. “Why would they want to waste energy?” Deborah Seligsohn of the World Resources Institute asked, adding that “if the U.S. changed the game in a fundamental way—if it really committed to dramatic reductions—then China would look beyond its domestic interests and perhaps go much further.” Perhaps it would embrace more expensive and speedier change. In the meantime China’s growth will blast onward, a roaring fire that throws off green sparks but burns with ominous heat.

“To change people’s minds is a very big task,” Huang Ming said as we sat in the Sun-Moon Mansion. “We need time, we need to be patient. But the situation will not give us time.” A floor below, he’s built a museum for busts and paintings of his favorite world figures: Voltaire, Brutus, Molière, Michelangelo, Gandhi, Pericles, Sartre. If he—or anyone else—can somehow help green beat black in this epic Chinese race, he’ll deserve a hallowed place near the front of that pantheon. □

The roads of China bear witness to the struggles of energies past and future. In Shaanxi Province coal trucks jam traffic for hours on their way to power plants near eastern cities. In Beijing a tractor trailer with two giant turbine blades is allowed to travel only at night as it rolls toward a wind farm 300 miles away in Inner Mongolia.



THE SECRET

(Chinese)

INGREDIENTS OF

(almost)

EVERYTHING

□□□□□□□□□□□□□□□□□□□□□□

From smart phones to hybrid vehicles to cordless power drills, devices we all desire are made with a pinch of rare earths—exotic elements that right now come mostly from China.

Samarium, one of the 17 rare (but widely useful) earths, helps convert sound into electricity in the magnetic pickups of electric guitars. It is also in the control rods of some nuclear reactors.



Actual size





By Tim Folger

M

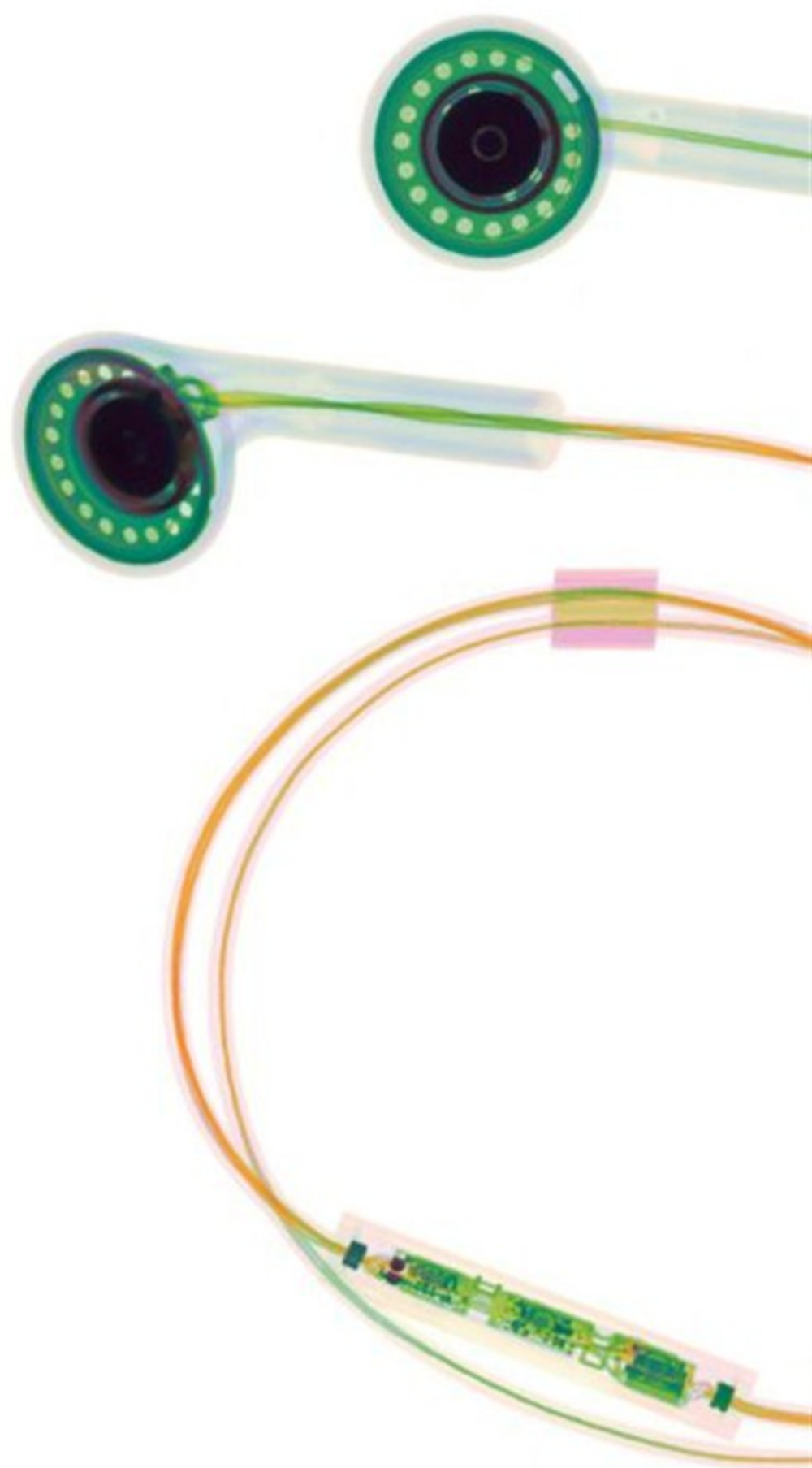
ost of us would be hard-pressed to locate Inner

Mongolia, Jiangxi, or Guangdong on a map. Yet many of the high-tech devices we depend on—cell phones, laptops, and hundreds of others—would not exist without an obscure group of elements mined, sometimes illegally, in those three and other regions of China.

.....

Rare earths, as the elements are called, were discovered beginning in the late 18th century as oxidized minerals—hence “earths.” They’re actually metals, and they aren’t really rare; they’re just scattered. A handful of dirt from your backyard would probably contain a smidgen, maybe a few parts per million. The rarest rare earth is nearly 200 times more abundant than gold. But deposits large and concentrated enough to be worth mining are indeed rare.

The list of things that contain rare earths is almost endless. Magnets made with them are much more powerful than conventional magnets and weigh less; that’s one reason so many electronic devices have gotten so small. Rare earths are also essential to a host of green machines, including hybrid cars and wind turbines. The battery in a single Toyota Prius contains more than 20 pounds of the rare earth element lanthanum; the magnet in a large wind turbine may contain 500 pounds or more of neodymium. The



Smart phones

Rare earths help phones (and MP3 players) emit sound and light. Neodymium magnets animate the speaker, the vibrating motor, and the tiny earbuds. LCD screen colors are produced by europium (reds) and terbium (greens).

HUGH TURVEY (X-RAY, HAND-TINTED)





Military vision

The U.S. military also depends on China's mines. Night-vision goggles (above) require lanthanum, gadolinium, and yttrium. Samarium magnets, which can withstand intense heat, help control Predator drones and Tomahawk cruise missiles.

Medical scans

Gadolinium also serves as a contrast agent in magnetic resonance imaging, or MRI, helping surgeons distinguish diseased from healthy tissue. In the scan at right it highlights a brain tumor (colored orange for clarity).

Green machines

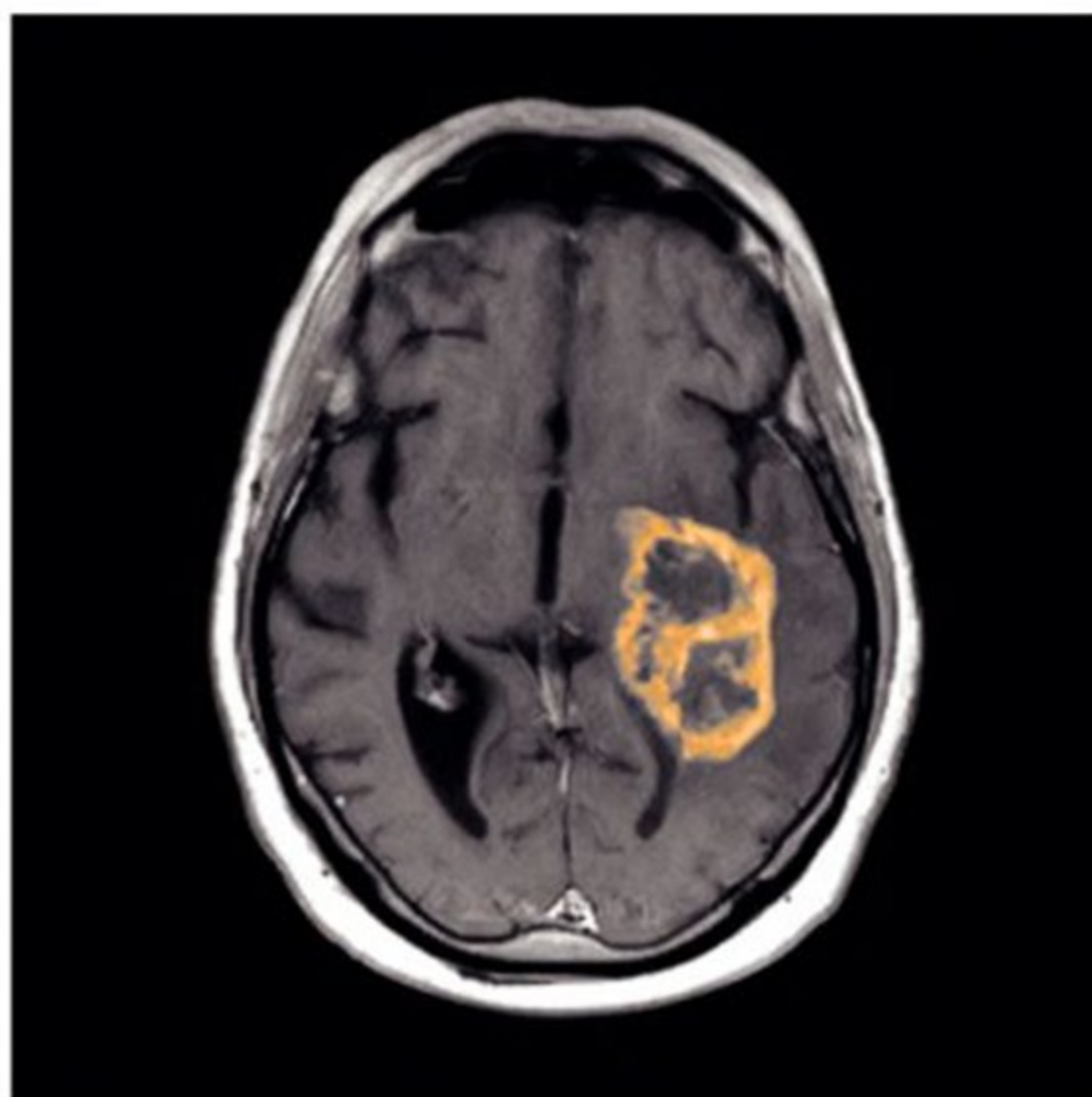
Hybrid cars would not exist without rare earth elements—lanthanum for their batteries, neodymium magnets for their electric motors. A wind turbine may contain hundreds of pounds of neodymium; a compact fluorescent lightbulb, much smaller amounts of yttrium and terbium.

And much else...

such as protecting eyes and beverages from ultraviolet radiation. Praseodymium, erbium, and neodymium tint sunglasses; cerium in wine-bottle glass promotes absorption of UV light. Some power tools rely on neodymium or dysprosium magnets to shrink their motors.

“They’re all around you. They’re hidden unless you know about them.”

—Karl Gschneidner, metallurgist



CLOCKWISE FROM TOP: MARK THIESSEN, NGM STAFF (4); MID-DELAWARE IMAGING; DRIVE IMAGES, ALAMY

SEVENTEEN ESSENTIALS

The rare earths are 17 metals that cluster together on the periodic table—15 of them, from lanthanum to lutetium, form a continuous series—and in ore deposits too. Malleable, reactive, magnetic, refractive, they’re small ingredients of many big things.



21 SCANDIUM

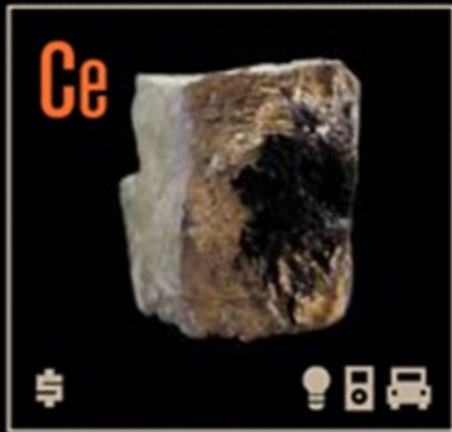


39 YTTRIUM

Scandium and yttrium lie outside the rare earth series but are chemically similar.



57 LANTHANUM



58 CERIUM



59 PRASEODYMIUM



62 SAMARIUM



63 EUROPIUM



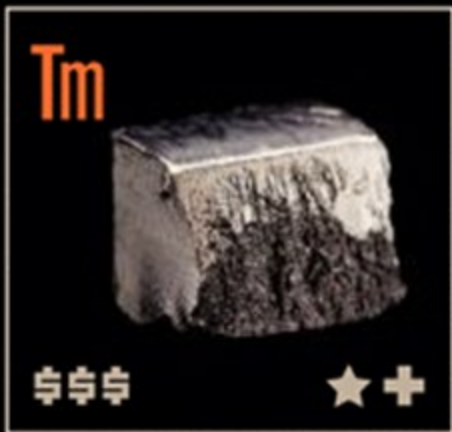
64 GADOLINIUM



67 HOLMIUM



68 ERBIUM

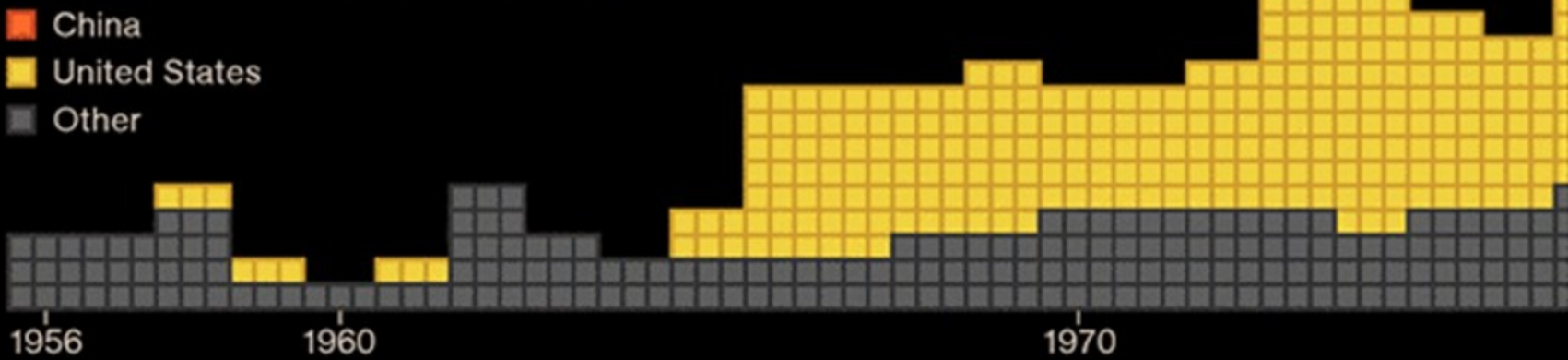


69 THULIUM

Who produces them

As rare earth mining took off in China, U.S. and other producers could no longer compete. The world market now depends on China, which already uses most of its output to supply its own booming factories. But other countries still have large minable reserves of rare earths.

Rare earth production, metric tons



Wide-ranging uses and prices

Lanthanum and cerium—catalysts in refining oil to gasoline—are cheap and abundant. Lutetium, one of the rarest and most expensive, is in PET scanners. Low-cost erbium is in optical fibers.

Metal price per pound

As of March 1, 2011

- \$ \$60-199
- \$ \$ 200-999
- \$ \$ \$ 1,000 and above

NORTH AMERICAN PRICES ARE SHOWN, BASED ON STANDARD PURITIES AND COMMONLY ORDERED QUANTITIES.

Nd



\$ ★ + ⚡ 📺 🚗

60 NEODYMIUM

Pm

Produced by nuclear fission, not mined

61 PROMETHIUM

Tb



\$ \$ ★ + ⚡ 📺 🚗

65 TERBIUM

Dy



\$ \$ + ⚡ 📺 🚗

66 DYSPROSIUM

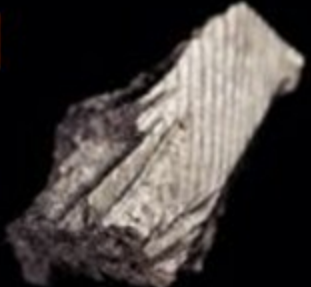
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70 YTTERBIUM

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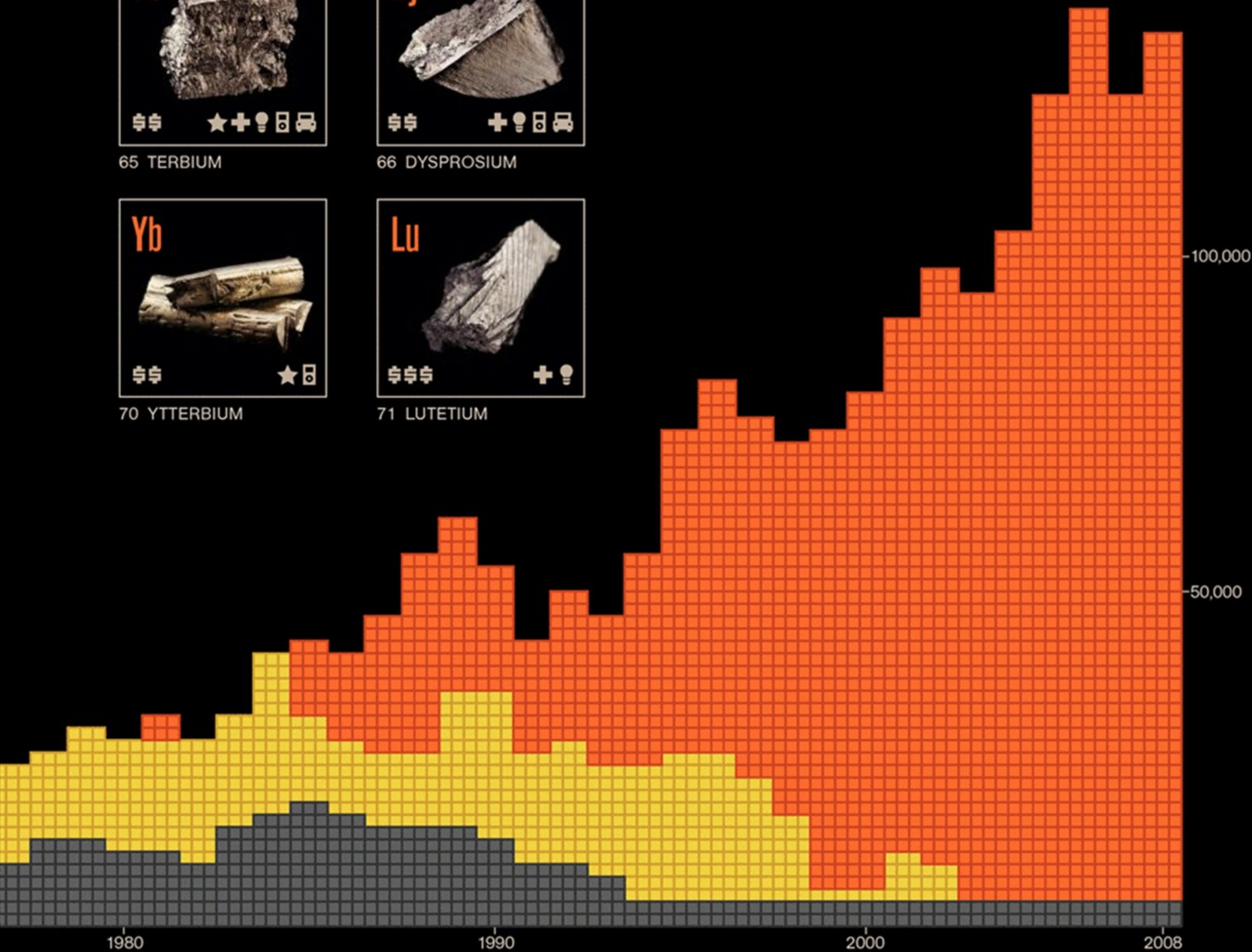


\$ \$ \$ + ⚡

71 LUTETIUM

- Use
- ★ Military
 - + Medical
 - ⚡ Energy
 - 📺 Consumer products
 - 🚗 Transportation

ALL POSSIBLE USES AND APPLICATIONS MAY NOT BE SHOWN.



U.S. military needs rare earths for night-vision goggles, cruise missiles, and other weapons.

"They're all around you," says Karl Gschneider, a senior metallurgist with the Department of Energy's Ames Laboratory in Ames, Iowa, who has studied rare earth elements for more than 50 years. "The phosphors in your TV—the red color comes from an element called europium. The catalytic converter on your exhaust system contains cerium and lanthanum. They're hidden unless you know about them, so most people never worried about them as long as they could keep buying them."

Now a lot of people are worried.



China, which supplies 97 percent of the world's rare earth needs, rattled global markets in the fall of 2010 when it cut off shipments to Japan for a month during a diplomatic dispute. Over the next decade China is expected to steadily reduce rare earth exports in order to protect the supplies of its own rapidly growing industries, which already consume about 60 percent of the rare earths produced in the country. Fears of future shortages have sent prices soaring. Dysprosium, used in computer hard drives, now sells for \$212 a pound, up from \$6.77 eight years ago. Over just two months last summer, prices on cerium jumped more than 450 percent. World demand will probably exceed supply before the end of 2011, says Mark A. Smith, president and CEO of Molycorp, an American company that reopened a rare earth mine at Mountain Pass, California, last year.

"We're in a supply crunch right now, and it's a pretty severe one," says Smith. "This year the demand will be 55,000 to 60,000 tons outside of China, and everyone's best guess right now is that China will be exporting about 24,000 tons of material. We'll survive because of industry inventories and government stockpiles, but I think 2011 will be a very, very critical year in terms of supply and demand."

Tim Folger wrote about the changing climate of Greenland in the June 2010 issue.

Concentrated force

A neodymium-based magnet is many times stronger than a conventional ferrite magnet of the same size; this one is holding a foot-long, one-and-a-half-pound wrench. Rare earths "channel" the inherent magnetism of iron and other elements, amplifying their power to attract.



The demand shows no signs of abating. In 2015 the world's industries are forecast to consume an estimated 185,000 tons of rare earths, 50 percent more than the total for 2010. So with China holding tightly to its reserves, where will the rest of the world get the elements that have become so vital to modern technology?

Although China currently monopolizes rare earth mining, other countries have deposits too. China has 48 percent of the world's reserves; the United States has 13 percent. Russia, Australia, and Canada have substantial deposits as well. Until the 1980s, the United States led the world in rare earth production, thanks largely to the Mountain Pass mine. "There was a time we were

If you own a smart phone, it may contain **contraband rare earths** from southern China.

producing 20,000 tons a year when the market was 30,000 tons,” says Smith. “So we were 60-plus percent of the world’s market.”

American dominance ended in the mid 1980s. China, which for decades had been developing the technology for separating rare earths (not easy to do because they’re chemically so similar), entered the world market with a roar. With government support, cheap labor, and lax or nonexistent environmental regulations, its rare earth industries undercut all competitors. The Mountain Pass mine closed in 2002, and Baotou, a city in Inner Mongolia (an autonomous region of China), became the world’s new rare earth capital. Baotou’s mines hold about 80 percent of China’s rare earths, says Chen Zhan-heng, director of the academic department of the Chinese Society of Rare Earths in Beijing. But Baotou has paid a steep price for its supremacy. Some of the most environmentally benign and high-tech products turn out to have very dirty origins indeed.

Rare earth mines often also contain radioactive elements, such as uranium and thorium. Villagers near Baotou reportedly have been relocated because their water and crops have been contaminated with mining wastes. Every year the mines near Baotou produce about ten million tons of wastewater, much of it either highly acidic or radioactive, and nearly all of it untreated. Chen maintains that the Chinese government is making an effort to clean up the industry.

“The government has already made strict regulations to protect the environment and weed out the backward techniques, equipment, and products,” Chen wrote in an email. “Those factories without abilities of environmental protection will be closed or merged with bigger companies.”

The Chinese government may eventually be able to regulate the large rare earth mining

industry around Baotou. But some of the smaller mines in southern China will be more difficult to control—because they’re operating outside the law to begin with. Violent criminal gangs run dozens of heavily polluting—and profitable—rare earth mines in Jiangxi and Guangdong Provinces. Xinhua, the official Chinese news agency, has reported that criminals smuggled 20,000 tons of rare earths from the country in 2008, nearly a third of the total rare earth exports for that year. If you own a smart phone or a flat-screen television, it may contain contraband rare earths from southern China.

“People don’t understand how totally corrupt the system in China is, with local party people aiding and abetting criminals in a very substantial way,” says Alan Crawley, CEO of Pacific Ores Metals & Chemicals, a trading company in Hong Kong. Crawley speaks from experience. One of his colleagues was murdered 11 years ago by Guangdong gangsters. “The Hong Kong police can’t do anything,” he says. “The killers fled back to the mainland.”

The world is now scrambling to find other sources of supply; the development of rare earth mines in the U.S., Australia, Russia, and other countries may eventually cut into the smugglers’ business. Molycorp intends to produce 3,000 to 5,000 tons of rare earths from stockpiled ore at its Mountain Pass mine this year and has big expansion plans. “The current U.S. demand is somewhere between 15,000 and 18,000 tons per year,” says Smith. “In principle, Mountain Pass could eventually make the United States independent in rare earths.” According to Chen, China’s present dominance of the market is not in its own long-term interests. “This situation is obviously not sustainable,” he noted, “for China’s rare earth industry and for the world’s high-tech industry.” □

LECTURE

▶ **Hang Out With Jimmy Chin**

Expert climber and photographer Jimmy Chin (right) was born to shoot our May cover story on extreme climbing in Yosemite. See him present some of his jaw-dropping photographs and the stories behind them at National Geographic in Washington, D.C., on June 2 at 7:30.


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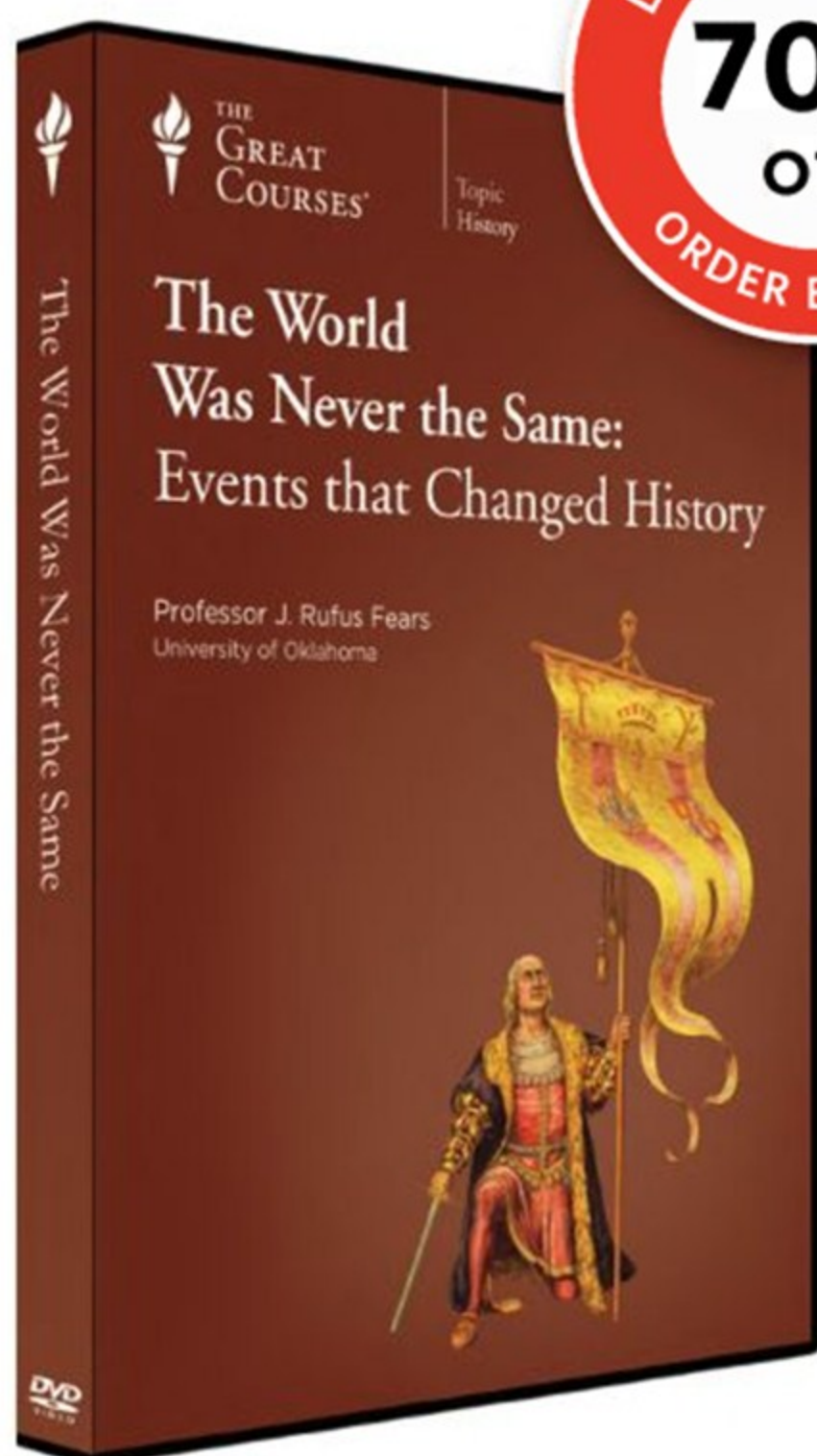


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The Hegira (A.D. 622)
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19. The Defeat of the Spanish Armada (1588)
20. The Battle of Vienna (1683)
21. The Battle of Lexington (1775)
22. General Pickett Leads a Charge (1863)
23. Adam Smith (1776) versus Karl Marx (1867)
24. Charles Darwin Takes an Ocean Voyage (1831)
25. Louis Pasteur Cures a Child (1885)
26. Two Brothers Take a Flight (1903)
27. The Archduke Makes a State Visit (1914)
28. One Night in Petrograd (1917)
29. The Day the Stock Market Crashed (1929)
30. Hitler Becomes Chancellor of Germany (1933)
31. Franklin Roosevelt Becomes President (1933)
32. The Atomic Bomb Is Dropped (1945)
33. Mao Zedong Begins His Long March (1934)
34. John F. Kennedy Is Assassinated (1963)
35. Dr. King Leads a March (1963)
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After Flames A veil of gauze protects a patient named Zahara from flies in a burn ward in Herat, Afghanistan. Afghan women who set themselves on fire may do so to escape abuse at home, believing they will die instantly. Yet many linger on with terrible injuries. Photographer Stephanie Sinclair first covered the issue of self-immolation by Afghan women in 2003. That led to an eight-year project on child marriage. She says, “I needed to start researching what would be so bad in these women’s lives that they would take this drastic measure.” —*Whitney Hall*



BEHIND THE LENS

Did this woman, Zahara, burn herself?

SS: The placement of her wounds suggests that she set herself on fire, but at the time of my visit she denied it. Denial is common at the hospital because patients are often afraid they will receive lesser care for self-inflicted wounds. The act of self-immolation brings shame upon the family, which is another reason women deny what is in many cases a failed suicide attempt.

How are child marriage and self-immolation connected?

More than half the women I met in the burn ward were married very young: 9, 10, or 11. It was clear they were miserable. Many of them had suffered

long periods of mental trauma during their early marriages. Then they heard other women had set themselves on fire, and they saw it as a way out, or even what I see as a cry for help. Because they haven't been educated, they

don't realize the consequences of living through the burns, of living with disfigurement. Girls are often pulled out of school as soon as they're engaged. Keeping them in school works against both child marriage and self-immolation.



Give An *Inspiring* Gift



Pat Minnick included National Geographic in her financial plans.

In 2007 Pat Minnick, a professional artist, decided to establish a charitable gift annuity to support National Geographic.

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1916

A Small Wedding

Upper-class Korean children pose for a wedding portrait in this 1916 photo, an image perhaps acquired for—but not published in—the July 1919 *Geographic* article “Exploring Unknown Corners of the ‘Hermit Kingdom.’” This bride and groom, ages 10 and 12 respectively, were likely married only ceremonially, living in separate quarters of the boy’s home until their elders decided otherwise. Among the aristocracy, such child marriages were arranged to strengthen ties between families.

Though the children are shown in traditional headwear for Korean brides and grooms, they do not wear wedding clothing. Notes Yeon Ji Hwang of the Korean Consulate’s Cultural Service, traditional ceremonial clothes “would be much too big for the couple to wear.” —Margaret G. Zackowitz

🔗 **Flashback Archive** Find all the photos at ngm.com.

PHOTO: MARY G. LUCAS, NATIONAL GEOGRAPHIC STOCK



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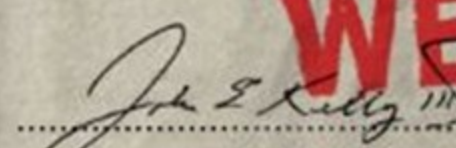
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